

ENCYCLOPEDIA OF TRANSPORTATION

Social Science and Policy



Mark Garrett

EDITOR

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TRANSPORTATION

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Social Science and Policy

Volume 1

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University of California, Los Angeles

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Airplane Navigation Systems
Automated Guideway Transit
Automated Landing Systems, Airplane
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Systems
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Automobile Design
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Emerging Technologies
Gasoline Engines
GPS, Automobile
Harbors, Design and Engineering of
High Speed Rail, Design and Technology of
Highway Design and Engineering
Highway Interchanges
Highway/Road Capacity
Hybrid Automobiles/Hybrid Electric Vehicles
Hydrogen Fuel Cells
Hypersonic Flight
Incident Detection Systems, Automobile
Information Technologies and Transportation
Inland Waterways, Operations and Management

Intelligent Transportation Systems
 Intelligent Vehicle Highway Systems
 In-Vehicle Computers
 Low-Emission Vehicles
 Maglev Systems
 Neighborhood Electric Vehicles
 Pneumatic Tube Transportation
 Railroad Automation Technology
 Smart Cars
 Smart Highways
 Street Design/Patterns
 Traffic Detection Systems
 Traffic Engineering
 Traffic Flow
 Transit System Analysis
 Transit System Technology
 Transit Systems Analysis
 Transit Tunnels, Design and Construction of
 Transit Vehicle Capacities, Loading Criteria and
 Zero-Emissions Vehicles

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 Highway Trust Fund
 Motor Fuel Taxes
 Parking Cash-Out Systems
 Parking Finance
 Road Pricing Schemes, U.S. and International
 Tax Increment Financing Districts
 Toll Roads, Private
 Transit Fares
 Transit Fares, Elasticity of Demand of
 Transit Finance
 Value Increment Tax
 Vehicle Miles Taxation and Fees

Transportation Legislation

Airline Deregulation Act of 1978
 Alternative Motor Fuels Act of 1988
 Americans with Disabilities Act of 1990
 Bureau of Budget Circular A-95
 Clean Air Act and Amendments
 Department of Transportation Act of 1966
 Energy Policy Act of 1992
 Energy Policy and Conservation Act of 1975
 Environmental Quality Improvement Act
 of 1970
 Executive Order 12898
 Federal Aid Highway Program

Federal Aid Road Act of 1916
 Federal Aviation Administration Reauthorization
 Act of 2009
 Federal Highway Act of 1921
 High-Speed Rail Investment Act of 2001
 Intermodal Surface Transportation Efficiency Act
 Motor Carrier Act (MCA) of 1980
 Moving Ahead for Progress in the
 21st Century Act
 National Energy Act of 1978
 National Environmental Policy Act
 National Highway System Design Act of 1995
 National Mass Transportation Assistance
 Legislation
 Safe, Accountable, Flexible, Efficient
 Transportation Equity Act: A Legacy for Users
 Section 504 Regulations on Accessibility
 Surface Transportation Assistance Act of 1978
 and 1982
 Transportation Equity Act for the
 Twenty-First Century
 Urban Mass Transit Act of 1964

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Activity-Based Models
 Destination Choice Models
 Equilibrium Modeling
 Freight Transport Models
 Full-Feedback Modeling
 Gravity Models
 Integrated Transportation and Urban Land Use
 Planning Models
 Microsimulation Models
 Mode Choice Models
 Network Modeling
 Origin–Destination Models
 Residential Location Models
 Route Assignment Models
 Supernetworks
 Traffic Forecasts
 Traffic Simulation
 Traffic Variables
 Transit System Analysis
 Transportation Modeling and Planning Software
 Travel Demand Forecasting
 Travel Model Calibration and Validation
 Travel Model Improvement Program
 Travel Modeling
 Travel Speed Models
 Trip Distribution Models

Trip Generation Rates and Models
Urban Transportation Modeling System
Vehicle Ownership Models

Transportation Modes

Aerial Tramways
Automobiles, Passenger
Bicycles
Bicycles, Electric
Buses
Commuter Rail
Electric Vehicles
Ferries
Heavy Rail Transit
Helicopters
Light Electric Vehicles
Light Rail Transit
Light-Duty and Pickup Trucks
Monorails
Motorcycles
Recreational Vehicles
School Buses
Ships
Sport Utility Vehicles
Streetcars/Trolleys
Subways/Elevated Trains
Taxicabs
Trains
Trolleybuses
Trucks
Vans
Walking

Transportation Organizations and Agencies

American Association of State Highway and
Transportation Officials
American Public Transportation
Association
Bureau of Public Roads
Environmental Protection Agency
Federal Aviation Administration
Federal Highway Administration
Federal Motor Carrier Safety Administration
Federal Railroad Administration
Federal Transit Administration
Institute of Traffic Engineers
Interstate Commerce Commission
Maritime Administration
National Highway Traffic Safety
Administration

National Transportation Safety Board
Pipeline and Hazardous Materials Safety
Administration
Surface Transportation Board
Surface Transportation Policy Project
Transportation Cooperative
Research Program
Transportation Research Board
U.S. Department of Transportation

Travel Behavior and Research

Air Travel
Automobile Trips
Bicycle Commuting
Business Travel
Car Sharing
Carpooling
Carpooling, Casual
Chicago Area Transportation Study
Commuter Paradox
Commuting
Cordon Travel
Derived Demand
Driver Licensing Rates
Employment Location
E-Shopping
Induced Travel
Latent Travel Demand
Mode Choice Models
Multiple Criteria Decision Making/Aiding
National Household Travel Survey
Noncommuter Travel
Ocean Cruise Industry
Parking Demand
Pedestrian Travel
Privately Owned Vehicles
Queuing and Shockwaves Measurement
Recreational Travel
Reverse Commuting
Single-Occupant Vehicle Trips
Traffic Psychology
Transit Demographics
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Transit Ridership
Transportation Studies
Transportation Surveys
Travel by Households
Travel by Mode
Travel by Persons
Travel Choice

Travel Demand
Travel Destinations
Travel Diaries
Travel Patterns by Income
Travel Patterns by Race/Ethnicity
Travel Patterns of the Elderly
Travel Patterns of Women
Trip Chaining

Triple Convergence
Vehicle Miles Traveled

Water Transportation Systems

Ferries
Inland Waterways, Freight Traffic and
Marine Transportation System
Ocean Passenger Travel

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Mark Garrett holds a Ph.D. in urban planning from the University of California, Los Angeles (UCLA) Luskin School of Public Affairs and a J.D. from the UCLA School of Law. For a number of years he was a practicing attorney in California specializing in land use, transportation, and environmental issues. He is currently serving as a member of the research faculty in the Lewis Center for Regional Policy Studies at UCLA and also teaches courses in the Department of Urban Planning. Garrett is the co-author with Martin Wachs of *Transportation Planning on Trial: The Clean Air Act and Travel Forecasting*, and has contributed to articles in the *UCLA Journal of Environmental Law and Policy*, the UCLA journal



Critical Planning, the *Berkeley Planning Journal*, the *Transportation Research Record*, and the *Journal of the American Planning Association*.

Garrett has been an adjunct professor in the Saint Louis University (SLU) School of Law and a faculty member in the Department of Policy Studies in SLU's College of Education and Public Policy. He has also taught at the Ohio State University, the University of Michigan, the University of Illinois, and Virginia Commonwealth University.

His current research focuses on sustainability and legal and social equity aspects of urban land use and transportation planning. He presently resides in Los Angeles, California.

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Introduction

We all rely on transportation. Whether it is flying to some faraway destination, taking a cruise, driving to work, bicycling through a park, or just walking around the block, we depend on a system of airports, harbors, railroads, highways, streets, and sidewalks to help get us where we need or want to go. Even without leaving our homes, we still depend on those who use transportation systems to deliver food to the grocery stores, consumer goods to local stores and shopping malls, and packages and mail to our front door. For the most part, all these systems, and more, require planning, construction, and maintenance, sometimes by private individuals and organizations but more often by various agents of government, whether at the local, state, national, or in some cases, international scale. None of us could survive unless legions of planners, policy makers, engineers, construction workers, air traffic controllers, drivers, ticket agents, road crews, police officers, school crossing guards, and many others worked tirelessly to keep the transportation network running smoothly and safely.

In addition to those who provide us with transportation systems, there are also many who study transportation systems and those who use them. They ask questions such as these: Where do people go? How do they get there? What types, or modes, of travel do they use? When are they most likely to travel? And perhaps most importantly,

why do they travel? All these questions are important to improving the service that transportation systems provide, but there is another set of questions that also concern those who deal with the policy aspects of transportation—namely, how do transportation systems affect our daily lives, and how will they shape our future?

Transportation consumes land and nonrenewable resources, generates noise, air pollution, and waste material, and results in the injury or death of thousands of individuals annually involved in transportation-related accidents. Increasingly in the industrialized world, people live far from their place of work or where they can shop. Millions of people spend a good part of their days in transit—some stuck for hours in traffic congestion. For others, their lack of access to either private or public transportation limits their mobility and greatly reduces their opportunity to lead useful and productive lives. All these issues, and others at varying times and in varying degrees, concern social scientists and policy makers involved in transportation. Accordingly, this volume brings together the latest research and thinking about transportation planning and policy by some of the leading figures in the field.

A Brief History of Transportation Policy

People have always moved about from place to place, often by following animal tracks that over

time become established roads. Mariners have long followed favorable winds and currents, passing their knowledge down to others. But, even conscious efforts to design and build transportation systems have a long history. The Phoenicians, Egyptians, Greeks, and Chinese all built harbors and canals to support long-distance trade. The Romans were renowned for constructing paved roads stretching across continents, as did the pre-conquest Peruvians.

The 19th Century. In North America, the desire of colonists to exploit their vast hinterlands led to the creation of the first National Road, an inconsistently built and maintained macadam pathway begun in 1811 at Cumberland, Maryland, and ultimately stretching through Pennsylvania, Ohio, and Indiana to Illinois—later U.S. Highway 40 and today more or less the route of Interstate 70—carrying settlers to Pittsburgh, Wheeling, Columbus, Indianapolis, and Terre Haute. At the beginning of the Industrial Age, steamboats carried passengers and freight deep into the new western territories after Fulton and Livingston's successful demonstration in 1807.

Forward-thinking entrepreneurs also developed canals to take goods to market, the Erie Canal completed in 1825 at a cost of \$7 million connecting Albany and Buffalo, New York, being perhaps the most famous—and linking the growing port of New York City to the Great Lakes and the vast resources of the northwest—but scores of others, large and small, were constructed in Virginia, Ohio, Indiana, and elsewhere. They were, however, quickly superseded by the newest marvel, the steam locomotives, whose spreading tracks began knitting together cities and regions into an ever-expanding economic network.

The meeting of the Union Pacific and Central Pacific Railroads at Promontory Summit, Utah, in 1869 completed the route selected by President Abraham Lincoln from Omaha, Nebraska, to Sacramento, California, forever joining the markets of the east to the west coast. Bridges of wood, iron, and later steel (the first use being the 1874 Eads Bridge in Saint Louis) spanning great rivers soon replaced ferry boats, making seamless travel possible across the nation. In the burgeoning industrial cities, omnibuses and steel-tracked horsecars carried workers from growing

residential enclaves to their work in factories and towering office buildings in the emerging central business districts. By the height of the Industrial Age, the perfection of a practical electric motor and transmission lines (first put in service in Richmond, Virginia, in 1888) heralded the beginning of the streetcar era; trolleys and interurbans fanned out over the countryside, vastly expanding the size and shape of the modern city and setting the stage for its now characteristic pattern of sprawl.

Often this took place with little or no government involvement beyond granting local franchises to transportation operators for ferries, streetcars, bridges, or toll roads (the Pennsylvania Turnpike began as a private toll road from Philadelphia to Lancaster in 1795), though other transportation systems like the Transcontinental Railroad mentioned previously required congressional funding. State and municipal regulation was likewise limited at first; some safety measures were adopted, and operators were typically charged with maintaining roadways under their control, but government was largely content to allow private enterprise to supply whatever the public desired in the way of transportation services.

The 20th Century. All that began to change at the dawn of the 20th century. Even before the newfangled automobile came into widespread use, bicycle enthusiasts and rural farmers began a campaign to improve the deplorable condition of the vast majority of the country's highways and byways. (Europe already had a history of national support for road construction.) This Good Roads Movement put pressure on states and the federal government to grade and pave dirt roads, connect rural areas to cities, and establish a national network of interstate highways. Congress passed the first Federal Aid Road Act in 1916, which provided funding for rural post roads, followed by the 1921 Federal Highway Act, which expanded funding for federal-aid highways to be built by publically funded state highway departments once approved by the new federal Bureau of Public Roads.

By 1923, the bureau had designated the complete federal-aid system, connecting every city over 50,000 in population, much of which would be completed by the late 1930s. Federal funds could

not at the time be used on urban roadways, and so, the program was still a decidedly rural one, though in urban areas, traffic congestion was becoming an increasing concern. The first federal gasoline tax, a mere 1 cent per gallon, was passed in 1932 as a temporary revenue measure but proved so lucrative that it was easily renewed in 1933 under the Roosevelt administration, which also backed legislation to fund urban road projects. The Hayden-Cartwright Act of 1934 ended the prohibition on using federal aid funds in urban areas and designated urban secondary roads as part of the federal aid highway system, thereby providing routine federal transportation aid to urban areas.

In 1939, General Motors Corporation sponsored a hugely popular exhibit called Futurama at the New York World's Fair, extolling the benefits of a safe, modern, high-speed national highway system and documenting the company's efforts in a promotional film titled *To New Horizons*, designed to build even more support for the project among the public and important policy makers. Perhaps not coincidentally, also in 1939, President Roosevelt endorsed the federal Bureau of Public Road's master plan for a national system of limited-access roadways covering 27,600 miles and extending the routes directly into urban areas. This road network was to be accessed only at interchanges, grade separated from cross traffic and trains, and free of tolls.

The new superhighways were to penetrate to the very heart of every major U.S. city, and larger metropolitan areas would have both inner and outer beltways. While widely popular, plans for the system were shelved while the nation struggled through the Great Depression and World War II. By 1944, interest in public highway projects as a way to ease the transition to a peacetime economy led to enactment of the Federal Aid Highway Act of 1944, which designated up to 40,000 miles of high-speed, limited-access freeways. The official routes, published in 1947, included 3,900 miles of highway extensions within urban areas and another 2,200 miles, also to be built within urban areas, seen as important to gaining urban political support for the highway program.

In the years following World War II, these efforts bore fruit in the form of the 1956 Federal Aid Highway Act, which financed the now 41,000-mile National System of Interstate and

Defense Highways. Signed into law by President Eisenhower, who as a young army officer had taken part in a two-month cross-country military convoy intended to highlight the poor conditions of the nation's roads, and who as World War II general saw firsthand the military and civilian potential of the German *Autobahn*, the legislation marked the beginning of the American freeway-building era. Congress increased the gas tax to 3 cents a gallon, placing these and other excise revenues in a Highway Trust Fund to be used exclusively for highway projects. Many of those inner-city freeways would become part of local urban renewal projects, frequently targeting poor and minority neighborhoods for removal and thus seriously tarnishing the freeway program's reputation. For returning veterans and other white citizens who qualified for low-interest home loans, though, the 1956 act and subsequent federal highway legislation literally paved the way to the suburbs and the American Dream.

The American obsession with road building did not extend to providing urban mass transit, which unlike in Europe and elsewhere, was historically not seen as a government concern. Transit companies, then mostly privately owned and struggling financially after a brief surge in popularity during World War II, soon succumbed to the increasingly suburban and automobile-oriented lifestyle. Many bankrupt systems were eventually acquired by local governments, often with federal funds, as Congress began to haltingly address the growing transportation problems of urban areas. The U.S. government in the 1960s began requiring continuing and comprehensive transportation plans be developed as a coordinated part of an overall regional planning process designed to rehabilitate urban areas and used its discretionary power over federal funds to promote that goal by conditioning project approvals on metropolitan-wide plans developed through what came to be known as the 3C planning process. Metropolitan Planning Organizations (MPOs) became the primary bodies responsible for highway and public transit planning in urban areas.

The Urban Mass Transportation Act of 1964 marked the first legislation to provide direct federal assistance for transit capital projects, authorizing discretionary grants for up to two-thirds of the net project costs of constructing or acquiring

mass transportation facilities and equipment in areas that had completed their regional plans. The 1966 amendments to the act provided federal matching funds for planning, engineering, and design of urban mass transportation projects and acquisition of remaining private transit operations. By the early 1970s, with most private transit properties having been purchased and bus fleets modernized and upgraded, a shift occurred in federal policy toward greater emphasis on expanding mass transit, particularly rail construction, in response to environmental and other social concerns and as a tool to counteract urban sprawl.

The Federal Aid Highway Act of 1973 introduced new flexibility in transit funding, significantly broadening the scope of MPO's responsibility to balance highway and transit spending. Since the mid-1970s, congressional transportation legislation has reflected a major shift in priorities toward addressing environmental concerns, beginning with the 1977 amendments to the Clean Air Act, which mandated greater coordination between transportation and environmental planning. The 1970s also ushered in an era of deregulation, particularly in the airline and passenger and freight railroad industries, generating greater competition but also raising concerns over the availability and quality of service, particularly in smaller market areas.

The 1990 Clean Air Act Amendments significantly expanded efforts to curb transportation-related emissions by reducing the growth in automobile travel, in effect making pollution reduction the driving force behind transportation planning. This legislation was accompanied by the landmark Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, intended to develop an economically efficient and environmentally sound national intermodal transportation system. ISTEA reinforced the planning requirements of the Clean Air Act by requiring a statewide transportation planning process that considers economic, energy, environmental, and social effects of highway and transit programs and projects. The acts require new, detailed, accurate analyses of the potential impacts of transportation improvements on congestion, travel, and land use but, most importantly, seek to coordinate planning over air, land, or sea, and for all modes of travel, whether

by planes, trains, automobiles, transit, bicycles, or even walking.

Current Issues

What does the future hold for transportation policy and research? Environmental issues will undoubtedly continue to be at the forefront as the world grapples with climate change: How do we reduce the use of polluting fossil fuels, particularly given increasing demand for automobiles brought on by the emerging economic wealth in places like China. And, if we do begin phasing out gasoline engines, how do we build the infrastructure—a network of charging stations like those now available for petroleum-based fuel—to make the transition to electric-powered vehicles possible? Will any success in reducing pollution even be enough, or must we begin to fundamentally rethink our reliance on private vehicles, however powered, or face more unproductive time spend in traffic jams?

Another continuing area of concern is safety and security, such as how to reduce the number and severity of automobile accidents, how to make car and plane crashes more survivable, and how to reduce the risks from terrorism, especially given the increasing reliance on electronic transportation monitoring and guidance systems that could be vulnerable to cyber attacks?

Future transportation planning and policy will undoubtedly continue to be tied to our use of land. Can we encourage new urban forms that fight sprawl and make it easier to use public transit? New movements, such as “complete streets,” challenge us to rethink our transportation systems as an integral component of the public space, providing for walking, bicycling, autos, and public transit in ways that enhance the urban experience rather than erecting more barriers to social and personal interaction. On a larger scale, as globalization takes greater hold, and more and more raw materials and finished products are being shipped around the world, what will the next generation of airports, shipping terminals, and distribution routes look like? Can transportation systems adapt to the changing patterns of urbanization and vice versa?

Other continuing concerns reflect how to pay for our existing transportation systems, many of which are in great need of repair or upgrades to meet growing demand. As we make substantial

investments in our transportation infrastructure, the question of the equitable distribution of benefits and costs will become even more critical. Should transportation be privatized, or should the public sector remain primarily responsible? Which modes should be subsidized? Who should pay: users, the general public, or some combination?

How will the information revolution affect the need to travel and the ways we travel? Can it be used to connect travelers with useful, real-time information or even be used to control the movements of both public and private vehicles? What impact will the growth of social media have on transportation? Perhaps the information age will severely reduce our need to travel as more and more of our daily needs can be met electronically. But if that is to be, what alternative investments should we be making? In some sense, the changes taking place are so new that it is hard to even imagine what questions to ask. Is it too early to start thinking about building skyports to serve low-orbit commercial space flights?

There are also institutional challenges ahead. Are there better ways to predict and plan for travel demand, both personal and commercial? Who should decide what to do with the

increasingly detailed personal travel information collected by mobile telecommunications devices? What role should the public play in deciding the future of the next generation of transportation systems? Many of the great planning disasters have revolved around transportation projects that failed to consider their social and environmental impacts and relied too heavily on technical expertise without consulting with, much less collaborating with, those affected by official decision making. Can transportation policy and planning be more democratic? Can they become more responsive to the needs of the poor and those with limited mobility? And, if so, has the era of the mega transportation projects in the United States drawn to a close?

These and many other critical issues facing the United States and the rest of the world are addressed, if not completely answered, among the many entries that follow. I would like to thank the many generous contributors who gave their valuable time and considerable knowledge in helping realize this project.

Mark Garrett
Editor

Chronology

ca. 4000 B.C.E.: Roads in the Mesopotamian city of Ur are paved with stone, making them among the first manufactured roads in the world.

ca. 3300 B.C.E.: Log “corduroy” roads are built across marsh ground near Glastonbury, England, by laying individual logs perpendicular to the movement of traffic.

ca. 3000 B.C.E.: Roads paved with brick are constructed in India.

ca. 500 B.C.E.: The Persian emperor Darius I builds a great network of roads, including the royal road from Susa to Sardis.

312 B.C.E.: Construction begins on the Roman road known as the *Via Appia* or Appian Way, running from Rome to Brindisi in southwestern Italy.

ca. 47 C.E.: Construction by Roman legions begins on the Fosse Way in Britain, a road linking Somerset with Lincoln.

ca. 610: In China, construction begins of the Grand Canal linking the Yangtze and Yellow Rivers.

1271: The Venetian merchant Marco Polo sets off for Asia; he returns almost 25 years later, and

his accounts of Eastern lands make him famous, although some there was dispute whether he had actually visited some of the places he described.

1391: In Germany, construction begins on a canal to link the Baltic and North Seas.

ca. 1500: In Milan, the first modern canal lock gates are installed.

ca. 1500: In South America, the Inca Empire includes a vast network of roads designed for caravans of llamas.

1610: In Britain, stagecoach service begins operation between Edinburgh and Leith; it is the first such service to use regularly spaced posthouses to change horses.

1630: The British entrepreneur Huntington Beaumont builds plank roads to accommodate heavy, coal-laden carts drawn by horses.

1660s: In Austria, an iron-spring suspension system for coaches is developed that greatly improves the comfort of the ride and helps popularize coach travel, as opposed to riding horseback.

1681: In France, the Briare Canal is completed, joining the Seine and Loire Rivers; its original

purpose was to transport grain, and it was later used for wine, timber, and other products.

1706: In Britain, Parliament passes the first statute creating a Turnpike Trust to construct and oversee the country's roads and to levy tolls on vehicles traveling on them.

1755: In the United States, George Washington acquires Conestoga wagons to transport military goods; the principal design innovation of the Conestoga wagon, the curved floor that helps keep the contents from shifting, also made it a popular wagon for settlers crossing the American continent to settle in the West.

1758: In England, the Middleton Railway in Leeds is established by an act of Parliament, lending credence to its claim to be the oldest public railway in the world.

1774: The Scottish engineer and inventor James Watt builds an efficient, stationary steam engine, used at first to operate plumps and later for many industrial purposes.

1784: In England, postal service by horse-drawn coach is introduced; the first postal run was from Bristol to London, but service was quickly expanded to include other cities, including Edinburgh in 1786.

1789: The U.S. Congress appropriates funds for lighthouses, buoys, and beacons and federalizes the lighthouses already existing.

1790: In Scotland, the Forth and Clyde Canal opens, crossing the Scottish mainland and linking the Firth of Forth with the Firth of Clyde.

1806: In the United States, legislation authorizing construction of the first federal highway, the National Road connecting Ohio with the Atlantic Coast, is signed by Thomas Jefferson.

1807: In the United States, Robert Fulton launches the first successful commercial steamboat, the *Clermont*, on the Hudson River, where it carries passengers between New York City and Albany, a distance of about 150 miles.

1813: The first successful steam locomotive, the "Puffing Billy" designed by William Hedley, begins operation at the Wylam colliery near Newcastle on Tyne, England.

1817: In Germany, Baron Karl von Drais invents a "walking machine" that resembles a bicycle without pedals or a chain; it consists of two wheels in a wooden frame and was used by straddling the frame, pushing off against the ground with your feet, and gliding.

1825: In the United States, the Erie Canal begins operation, providing the first water link between the Hudson River and the Great Lakes, thus allowing goods to be transported from the Atlantic Ocean into the central United States without having to be carried overland; the first ship to use the canal, a packet boat named the *Seneca Chief*, departs from Buffalo, New York, on October 26 and arrives in New York City on November 4.

1825: In England, the first steam-powered railway service begins operation between Stockton and Darlington.

1827: In New York City, Abraham Brower establishes the city's first public transportation service along Broadway, provided by a 12-seat stagecoach that followed an established route and charged a set fare to passengers.

1827: In New York City, the banker John Mason organizes a street railway with horse-drawn vehicles and cars running on metal tracks; the cars are built by John Stephenson, who becomes a major supplier of horse-drawn streetcars.

1828: In Germany, the horse-drawn Prince William Railway begins operation to haul coal; it begins carrying passengers in 1833 and, in 1847, begins using steam power.

1830: George Stephenson begins operating a passenger railway between Manchester and Liverpool.

1832: In Sweden, the Göta Canal is completed, forming part of a waterway reaching from the Atlantic Ocean to the Baltic Sea.

1832: The *Sirius* becomes the first steamship to cross the Atlantic; the journey takes nine days.

1840: The first contract to transport mail across the Atlantic Ocean by steamship is granted to Samuel Cunard.

1843: Completion of the Thames Tunnel under the Thames River in London; used originally for pedestrians, it later was used as a railway tunnel.

1847: Great Britain becomes the first country to adopt standard time zones, motivated by the growth of the rail system and the need to have a standard method of keeping time to facilitate accurate timetables.

1849: Public transportation begins in Toronto in the form of horse-drawn omnibuses designed by cabinetmaker Burt Williams and operating along King Street and Yonge Street.

1852: In Chicago, omnibuses begin providing public transportation; the first buses were horse-drawn stagecoaches that took passengers between rail stations.

1853: The first passenger railway in India begins operation, running from Bombay to Thane; several previous railways were already in operation but were used to transport materials rather than passengers.

1854: A steam railway begins operation in Victoria, running from Flinders Street to Sandridge; routes were soon added running to St. Kilda (1857), North Brighton (1859), and Essendon (1860).

1859: The first street railways in Chicago begin operation; the cars are horse-drawn omnibuses with steel wheels and run on rails attached to the plank streets.

1861: In Toronto, the first horse-drawn street railways begin operation along King Street, Yonge Street, and Queen Street.

1862: In the United States, President Abraham Lincoln authorizes construction of the

Transcontinental Railroad (completed in 1869) by signing the Pacific Railway Act.

1863: The first underground railway begins operation in London, running from Padding to Farringdon Streets.

1864: In England, construction of the Clifton Suspension Bridge begins; designed by Isambard Kingdom Brunel, the bridge spans the River Avon and the Avon Gorge.

1865: The velocipede, or “Boneshaker,” an early proto-bicycle, is introduced; originally made entirely of wood, it has pedals attached directly to the front wheel.

1869: In Egypt, the Suez Canal at Port Said opens.

1869: In London, the East London Railway begins running steam trains through the Thames Tunnel.

1869: The American engineer George Westinghouse invents the railway air brake, replacing manual systems and greatly increasing the safety of rail travel; Westinghouse makes many improvements to the air brake over the years, and in 1893, the U.S. federal government requires automatic air brake systems on all interstate rail travel.

1869: In Melbourne, Australia, the city’s first public transportation fleet begins operation, as the Melbourne Omnibus Company begins operating 11 horse-drawn buses; by 1881, the fleet had expanded to 158 horse-drawn buses.

1869: In the United States, the transcontinental railroad is completed when the Union Pacific and Central Pacific Railroads meet at Promontory Summit in Utah.

1870: Elevated rail service begins in New York City, running along Greenwich Street and Ninth Avenue in Manhattan.

1870: The first all-metal bicycles are created, with pedals attached directly to the enlarged front wheel and solid rubber tires, which provided a smoother ride. One model, built by James Starley,

is called the penny farthing bike because of the different sizes of the two wheels.

1879: A French team, led by Ferdinand de Lesseps, begins construction on the Panama Canal.

1879: Sandford Fleming, a Scottish-born engineer working in Canada, popularizes the concept of standard world time zones, including establishment of the prime meridian at Greenwich, England, the location still used today.

1880: In the United States, the League of American Wheelmen, an organization of cyclists, is formed and lobbies for better roads.

1881: In Dunedin, New Zealand, the first cable tram line outside America begins operation; designed by George Smith Duncan, it begins operation with a single line, with a second added in 1883.

1883: A cable-powered railway begins providing service in New York City, running over the Brooklyn Bridge between Manhattan and Brooklyn.

1884: Thomas Stevens rides a bicycle across the United States from Oakland, California, to Boston, Massachusetts.

1885: In Melbourne, Australia, the city's first cable tram line begins operation; by 1891, a network of 17 miles of cable trams connected Melbourne with its surrounding suburbs, and the system remained in operation until 1940.

1885: The first automobile, the three-wheel Tri-Star, is built by the German engineer Karl Friedrich Benz; it is powered by an internal combustion engine.

1885: The German engineer Gottfried Wilhelm Daimler builds the first successful four-wheeled automobile; like the Tri-Star, it has an internal combustion engine.

1888: In Germany, members of the Benz family of automobile manufacturers drive a car 90 kilometers, from Mannheim to Pforzheim, to demonstrate the usability of the new vehicles.

1889: Bicycles begin using pneumatic rubber tires, creating a smoother ride.

1890: A cantilevered railroad bridge is built across the Firth of Forth in Scotland.

1890: In London, the City and South London Railway begins operation of the first deep-level electric tube railway in the world; it runs between Stockwell and King William Street, and station access is provided by a hydraulic lift.

1890: In Russia, work begins on the Trans-Siberian Railway.

1890: In Potsdam, German Otto Lilienthal begins making guided flights in a glider.

1892: In Toronto, the Toronto Railway Company is granted a 30-year franchise over the city's streetcar system and begins operating electric streetcars; by the end of 1894, electric cars have completely replaced the horse-drawn variety.

1893: The modern bicycle frame design, with its diamond shape, is introduced.

1897: In Chicago, the El, or elevated train service, begins operation in the central downtown area, called the Loop; the elevated train tracks allowed them to bypass the congested streets of Chicago.

1897: In Berlin, eight automobiles are exhibited at the first International Motor Show.

1898: The American woman's rights advocate Susan B. Anthony cites the bicycle as an important force in the liberation of women as the popularity of the bicycle encouraged simpler clothing styles while also increasing mobility.

1898: The Canadian American sailor Joshua Slocum becomes the first person to make a solo voyage around the world, a trip publicized in his 1900 book *Sailing Along Around the World*.

1900: In Illinois, the Sanitary and Ship Canal begins operation, reversing the flow of the Chicago River and bringing water from Lake Michigan to dilute the sewage of Chicago.

1900: In the United States, only one in 9,500 citizens owns a car, and only 22 percent of those run on internal combustion engines, with most of the rest being powered by electricity or steam.

1900: The first line of the Paris Metro begins operation, running from the Porte de Maillot to the Porte de Vincennes and providing transportation to the summer Olympic Games being held in Paris that year; 30,000 Metro tickets were sold on the first day of operation.

1901: In the United States, Samuel Pierpont Langley builds the first aircraft to be powered by an internal combustion engine.

1901: C. L. Horock designs the first modern shock absorber, the so-called telescope, which uses a piston with a one-way valve and air or oil to resist movement.

1902: In France, the industrialist Louis Renault introduces drum brakes for automobiles.

1902: In France, Leon Serpollet drives a steam car at 75 miles per hour, setting a land speed record. Shortly afterward, the record is broken by William K. Vanderbilt driving an internal combustion car; Vanderbilt reaches the speed of 76 miles per hour.

1903: Horatio Nelson crosses the United States by automobile in 65 days.

1903: In the United States, Wilbur and Orville Wright complete four sustained flights with a powered, controlled aircraft; the longest flight covers 852 feet.

1904: In Germany, Ludwig Prandtl presents a paper describing the concept of an aerodynamic boundary layer.

1904: The United States becomes the world's leading automobile manufacturer, surpassing France.

1904: The Interborough Rapid Transit (IRT) Company begins operating the first official subway system in New York City, with 9.1 miles of track running from city hall in downtown

Manhattan to 145th Street. The IRT gradually expands service to the other bureaus, adding service to the Bronx in 1905, to Brooklyn in 1908, and in 1915 to Queens.

1904: The United States begins work on the Panama Canal, taking over an effort previously abandoned by the French.

1906: In the state of Victoria, Australia, an electric tram line begins running from St. Kilda to Brighton; many more lines were constructed over the next 14 years, and in 1920, they were consolidated under the auspices of the Melbourne and Metropolitan Tramways Board.

1907: The Fifth Avenue Coach Company begins offering the first passenger motor bus service in New York City, running between Washington Square in Lower Manhattan and 90th Street.

1908: In Michigan, Henry Ford begins producing the Model T automobile, with more than 10,000 cars produced in the first year alone.

1908: In London, the three separate companies operating underground railway services begin coordination of their services, including the development of common signage and distribution of free pocket maps.

1910: Commercial air service is provided by the rigid airship *Deutschland*, developed by Ferdinand Zeppelin.

1912: The American aviator Glenn Curtis demonstrates *The Flying Fish*, the first successful flying boat.

1912: The ocean liner *Titanic*, operated by the White Star line, sinks in the North Atlantic on the way from England to America, killing more than 1,500 people.

1913: In December, the Panama Canal is completed, creating an unbroken waterway between the Atlantic and Pacific Oceans.

1913: The first subway in Latin America begins operations in Buenos Aires, Argentina.

1913: In Michigan, Ford Motor Company develops the first moving assembly line for automobile production, allowing cars to be made more cheaply and efficiently.

1914: In New York, Lawrence Sperry demonstrates the use of an automatic gyrostabilizer to keep an airplane level and on a straight course.

1915: In the United States, the National Advisory Committee for Aeronautics is created to foster and support aeronautical research.

1915: In New York City, the Brooklyn Rapid Transit Company begins offering subway service between the boroughs of Manhattan and Brooklyn; it will be taken over by the Brooklyn-Manhattan Transit (BMT) Corporation a few years later.

1916: In the United States, the Federal Aid Road Act becomes law, creating a program in which the federal government provides funding to the states to construct roads to facilitate mail delivery.

1918: Airmail service in the United States begins, with a flight from Washington, D.C., to New York City.

1919: U.S. Navy pilots cross the North Atlantic Ocean, from Newfoundland to London, making stops in the Azores and Lisbon.

1919: In Europe, the first air passenger service begins across the English Channel between London and Paris.

1920: The New York City subway system begins using coin-operated turnstiles rather than tickets; a ride first cost a nickel and was later raised to a dime.

1923: In the United States, construction begins on the Lincoln Highway, the first fully paved road to cross the United States; it will run through 13 states (14 after rerouting) on its course from New York City to San Francisco.

1924: In the United States, the National Conference on Street and Highway Safety, hosted by

Secretary of Commerce Herbert Hoover, brings together engineers, automobile manufacturers, and insurers to seek ways to reduce the number of deaths caused by automobile accidents.

1926: In the United States, Francis Wright Davis introduces the first power steering system in a Pierce-Arrow automobile.

1927: In May, American Charles Lindbergh makes the first nonstop solo flight across the Atlantic Ocean from New York to Paris.

1927: One out of every seven Americans owns a car.

1927: In June, Lester Maitland and Albert Hegenberger complete the longest open-sea flight to date, flying 2,400 miles from Oakland, California, to Honolulu, Hawai'i.

1932: American aviator Amelia Earhart becomes the first woman to fly solo across the Atlantic from Newfoundland to Ireland.

1932: The City of New York creates the Independent Rapid Transit (IND) railroad, the first city-owned subway line.

1933: The first commercial airliner, the Boeing 237, is introduced; it has two engines, variable-pitch propellers, and retractable landing gear and seats 10.

1933: In London, Harry Beck creates a diagram map for the Underground that remains in use, with modifications, to this day.

1934: The French *Citroën Traction Avant* becomes the first successful, mass-produced front-wheel-drive automobile.

1934: Germany begins construction on the first *autobahn*, or freeway; the first section, running from Frankfurt to Darmstadt, opens in 1935 and is so well-constructed for high speed travel that it is used for racing as well as transportation.

1935: The first subway system in the Soviet Union, the Moscow Metro, begins operation.

1935: The British engineer Robert Watson-Watt patents the first practical radar system; originally intended to study the weather, it proves useful in detecting incoming aircraft during World War II.

1935: In November, Pan American Airways begins the first transpacific airmail service between Manila and San Francisco.

1936: In October, Pan American Airways begins operating the first transpacific passenger air service.

1937: The jet engine is designed independently in England, by Frank Whittle, and Germany's Hans von Ohain.

1937: The German passenger airship Hindenburg catches fire in New Jersey, killing more than 30 people and shattering public confidence in rigid airships as a means of transportation.

1937: Amelia Earhart disappears somewhere in the Pacific during an attempt to fly around the world.

1939: The VS-300 helicopter, one of the first practical single-rotor helicopters, is designed for the U.S. Army by the Russian émigré Igor Sikorsky.

1939–45: In London, Underground Tube stations provide shelter from bombing raids and are also used as military command centers and for the storage of artworks.

1940: In the United States, engineer Karl Pabst designs the Jeep, which becomes a workhorse vehicle for the United States and allied forces in World War II.

1940: In Washington State, the Tacoma Narrows suspension bridge collapses into Puget Sound less than five months after it began carrying traffic; the collapse was caused by periodic motion or flutter caused by the wind.

1940: New York City purchases the Brooklyn-Manhattan Transit (BMT) and the Independent Rapid Transit (IRT) Corporations and becomes

the sole owner and operator of subway and elevated trains in the city.

1942: The Alcan, or Alaska–Canada, Highway, constructed largely as a military supply route during World War II, is completed; it runs from Dawson Creek, British Columbia, to Delta Junction, Alaska.

1945: In Wolfsburg, Germany, the first Volkswagen Beetle is manufactured; production of the Beetle continues until 2002.

1945: The Chicago Transit Authority (CTA) is created, bringing Chicago's mass transit systems under public ownership for the first time. By 1997, the CTA manage a system carrying 287 million riders annually on buses and 130 million on rapid transit cars.

1947: In California, U.S. Air Force pilot Charles Yeager becomes the first to fly faster than the speed of sound, that is, breaking the sound barrier.

1948: During the Cold War, Russia blocks surface access to the Allied sector of Berlin, Germany; in response, the Allies organize the Berlin Airlift to transport food, fuel, and other necessities to the city's residents by airplane.

1950: The *St. Roch*, a Canadian ship, becomes the first to circumnavigate North America, passing through both the Panama Canal and the Northwest Passage.

1952: The first commercial jet airline service, between London and Johannesburg, South Africa, begins operation using the De Havilland Comet.

1952: The American engineer Richard T. Whitcomb discovers the area rule, which becomes a fundamental aspect of airplane design.

1953: The New York City subway system begins using tokens, as the fare had risen to 15 cents and the turnstiles could only handle one type of coin.

1954: In the United States, the Wiley–Dondero Act creates the Saint Lawrence Seaway Development Corporation to develop the U.S. portions

of the Saint Lawrence Seaway between Lake Erie and Montreal.

1955: The last elevated public transit rail line closes in Manhattan, New York City, the Third Avenue El.

1956: The New York City Transit Authority shuts down its last two trolley lines, which ran in Brooklyn along McDonald Avenue and Church Avenue.

1956: In the United States, Congress passes the Interstate Highway Act to create a national system of limited-access, high-speed highways.

1957: In East Germany, the first Trabant, an automobile with a two-stroke engine, is produced; it becomes the most common car in East Germany and remains in production until 1991, when East and West Germany are reunified.

1960: The New York City Transit Authority ceases operation of the last trolley buses in the system.

1960: One in three Americans owns a car.

1962: The Trans-Canada Highway is completed, running from the Atlantic to the Pacific coasts and connecting all 10 provinces.

1962: Colorado businessman Leonard Rivkin introduces the first child car safety seat, called the Strolee National Safety Car Seat for Children.

1963: Positive crankcase ventilation (PCV) is introduced to automobile engines in an effort to reduce the emission of harmful gases.

1964: In California, construction begins on the Bay Area Rapid Transit (BART) system; in 1972, the first segment of the system, a 28-mile stretch between Fremont and MacArthur stations, begins operation.

1964: In the United States, the Urban Mass Transportation Act creates a program of matching federal grants to help states build urban mass transportation systems.

1964: In Japan, the first of the high-speed *Shinkansen*, or bullet train rail lines, begins operation, running from Tokyo to Osaka.

1965: New York City begins express bus service, with a line running from Staten Island to Brooklyn.

1965: The United States begins developing high-speed train service for the densely populated Northeast Corridor, authorized by the High Speed Ground Transportation Act of 1965.

1965: The U.S. Congress passes the Vehicle Air Pollution and Control Act to regulate automobile emissions.

1966: In the United Kingdom, an efficient electronic fuel injection system is developed for automobiles.

1967: In the United States, 46 people are killed when the Silver Bridge, running between Gallipolis, Ohio, and Point Pleasant, West Virginia, collapses; this accident helped motivate the inclusion of national standards for bridge inspection in the 1968 Federal Aid Highway Act.

1969: The Boeing 747, the first jumbo jet, or wide-body commercial airplane, begins operations.

1969: In Washington, D.C., construction begins on an underground rapid-transit rail system, known as the Metro; the first line begins operation in 1976, and the system is later extended to include parts of Maryland and Virginia.

1969: In New York City, reduced transit fares for senior citizens are introduced, a benefit extended in 1975 to disabled people as well.

1969: In the United States, high-speed Metroliner rail service between Washington, D.C., and New York City begins operation; the Metroliner service continues until 2006, when it is replaced by the Acela Express service.

1970: On April 22, the first Earth Day is held, reflecting growing interest in conservation and environmentalism, including the development

and expansion of public transportation systems and other alternatives to the automobile.

1971: In Melbourne, Australia, construction begins on an underground rail loop; a test train ran through it in December 1980, and regular passenger service began in January 1981.

1973: The Paris Metro system introduces turnstiles, replacing the system of punched paper tickets that had been used from the system's opening in 1900.

1976: In January, commercial service begins on the Concorde SST, a plane capable of flying at twice the speed of sound and making the trip from London to New York in 3.5 hours.

1977: Airplanes operated by KLM and Pan Am collide on a runway in Tenerife (the Canary Islands, Spain), killing 583 people in the deadliest accident in commercial aviation history.

1978: In the United States, the Airline Deregulation Act of 1978 liberalizes several aspects of air travel, including allowing airlines to reduce fares without needing the approval of the Civil Aeronautics Board and allowing new airlines to begin service on routes not protected by other carriers; however, smaller communities are guaranteed essential air services for an additional 10 years, with government subsidies if the routes are unprofitable.

1979: The Iranian Revolution disrupts oil production and exports from Iran, causing higher gasoline prices and shortages in the United States and increasing interest in fuel-efficient vehicles as well as alternative means of transportation; one response is Executive Order 12191, signed by U.S. President Jimmy Carter, which encourage federal employees to carpool to work.

1980: Japan becomes the world leader in automobile manufacturing, surpassing the United States.

1981: The first mass-produced mountain bike is introduced in the United States, helping popularizing mountain biking as a sport.

1981: In France, the first high-speed train service (*Train à Grand Vitesse*) begins operating between Paris and Lyon.

1981: In the United States, the Professional Air Traffic Controller's Association (PATCO) goes on strike; when most members refuse to return to work (government unions in the United States are not allowed to strike), President Ronald Reagan fires them, and PATCO is decertified by the Federal Labor Relations Authority.

1982: Braniff Airlines becomes the first U.S. scheduled airline in history to file for Chapter 11 bankruptcy protection; an administrative law judge later determines that Braniff's financial collapse was caused in part by the Airline Deregulation Act.

1984: New York becomes the first U.S. state to mandate the use of seat belts in automobiles for all passengers.

1985: The U.S. cyclist John Howard becomes the first person to break 150 miles per hour on a bicycle, achieving a speed of 152.3 miles per hour.

1987: In London, fire and safety regulations are upgraded after 31 people are killed in a fire caused by an escalator at the King's Cross Underground station.

1987: The European Commission introduces the first reforms intended to liberalize air transport among member countries, limiting the right of governments to determine air fares and giving airlines more flexibility to share seat capacity.

1988: Pan American Flight 103 blows up over Lockerbie, Scotland, killing 270 people; a British investigation later determines that the cause of the explosion was probably a terrorist bomb hidden in a radio-cassette player, and in 1991, two Libya intelligence agents are indicted for this crime.

1990: California passes the Zero Emission Vehicle Mandate, requiring 10 percent of the state's cars to produce no emissions by 2003, and 2 percent by 1998.

1991: In the United States, the Intermodal Surface Transportation Efficiency Act (ISTEA) emphasizes regional transit planning and gives states greater flexibility in planning mass transportation; it also mandates airbags as a safety feature in automobiles.

1992: In the United States, the Energy Policy Act encourages the development of automobiles powered by alternative fuels, including natural gas, battery power, and mixtures of gasoline and alcohol.

1993: The New York City Transit Authority introduces the MetroCard, an electronic-stored value card; it is gradually phased in throughout the system, and by 1997, the entire subway and bus system accepts MetroCards.

1993: In the United States, air traffic controllers fired after the 1981 strike are allowed to reapply for employment with the Federal Aviation Administration.

1995: In Tokyo, members of the Aum Shinrikyo cult release sarin gas on the Tokyo Metro, an act of domestic terrorism resulting in 13 deaths.

1996: General Motors begins producing the EV1, a mass-produced electric car; it ceases producing the EV1 in 1999.

1997: The European Commission introduces *cabotage* in the air transport sector, giving an airline from one member state the right to operate an air route within another member state.

1997: Toyota introduces the first commercial, mass-produced hybrid automobile, the Prius, and sells nearly 18,000 vehicles in the first year.

1998: The New York City Transit Authority begins using hybrid electric buses.

1999: The United States hands over sovereignty of the Panama Canal to Panama, fulfilling the terms of the Torrijos–Carter Treaties signed in the 1970s by U.S. President Jimmy Carter and General Omar Torrijos of Panama, which replaced the original agreement of 1903 between the countries.

2001: A coordinated series of terrorist attacks on the United States, including the World Trade Center in New York City and the Pentagon near Washington, D.C., all involving hijacked commercial air flights, spur the creation of the Transportation Security Administration (TSA) in the United States.

2003: In the New York City public transportation system, tokens are no longer accepted as of April on subways, and as of the end of the year on buses, as they have been replaced by the electronic stored-value MetroCard.

2004: In Shanghai, China, the first commercial maglev (magnetic levitation) train begins operating, running from the Longyang Road metro station to Pudong airport.

2005: In London, 52 people are killed in coordinated suicide bomb attacks on a bus and three Underground trains.

2005: The Airbus A380, the world's largest passenger aircraft, begins operation; it can carry more than 850 passengers.

2007: Panama begins a project to widen the Panama Canal and create new locks in order to accommodate larger ships, with completion scheduled for 2014.

2007: The case of an Atlanta lawyer draws attention to the possibilities of communicable disease being spread rapidly through modern transportation systems. The man, Andrew Speaker, had multidrug-resistant tuberculosis, yet took several international airplane flights, potentially exposing other passengers to the disease; upon return to the United States, he was placed in involuntary isolation (quarantine) for treatment.

2009: Nissan introduces the LEAF, an electric car that can travel 90 miles per hour and has a range of 100 miles on a full battery charge; the acronym stands for Loading, Environmentally friendly, Affordable, Family car.

2010: In Moscow, about 40 people are killed in two Metro stations as a result of suicide attacks.

2011: Somali pirates working in the Arabian Sea kill four American hostages, bringing increased attention to the problem of sea piracy and calling for stronger measures in response to the problem.

2012: A study by the Highway Data Loss Institute finds that the probability of accidents is reduced in cars that have a forward collision-avoidance system installed; adaptive headlights are also associated with reduced probability of accidents, but lane departure warning systems are not.

2012: In China, the world's longest high-speed rail line begins regular service from Beijing to Guangzhou; the trains travel the roughly 1,200-mile distance in about eight hours, while regular trains on a parallel track require 21 hours to complete the same route.

2012: A study by the Norwegian University of Science and Technology suggests that the environmental benefits of electric cars, as compared to gas-fueled cars, are not as great as previously assumed; among the causes were greater toxic waste produced by electric car factories and the use of toxic minerals in producing the car batteries.

2012: The U.S. Federal Aviation Agency releases a forecast predicting that, as measured by Revenue Passenger Miles (RPM), airline passenger travel will nearly double by 2032.

2012: The first private cargo rocket to supply the International Space Station is launched from Cape Canaveral, Florida; the rocket is built by the Space Exploration Technologies Corporation (SpaceX) and is part of a National Aeronautics and Space Administration (NASA) program to replace government-operated spacecraft with those operated by private companies for low-Earth orbit missions.

2012: The final report on a 2009 Air France plane crash killing 228 people attributes the crash to a combination of confusing alarm systems, faulty equipment, and lack of pilot training for the particular circumstance encountered (a high-altitude stall).

2013: In India, about 40 people are killed at the Allahabad railway station in an incident

described as a stampede caused by an overload of passengers (many of whom were pilgrims traveling to a religious festival), delayed rail service, and a sudden change in the routing of a departing train, causing several thousand people to surge onto a footbridge meant to accommodate fewer than 1,000.

2013: Mercedes Benz exhibits an electric car, the Mercedes Electric Drive, that has a quick-charge feature allowing it to travel 60 miles after being charged for two hours; the Electric Drive, which was developed in cooperation with Tesla Motors, is scheduled to go on sale in 2014.

2013: In the United States, federal budget cuts lead the Federal Aviation Administration to announce the closing of 149 air traffic control towers; several airports, including the Spokane International Airport and the Central Illinois Regional Airport, file lawsuits arguing that the closings would cause dangerous conditions.

2013: The Metropolitan Transportation Agency in New York City announces that almost \$5 billion will be required to repair damage caused by Hurricane Sandy, which hit the city in October 2012.

2013: In its "Global Status Report on Road Safety 2013," incorporating data from 182 countries, the World Health Organization reveals that worldwide 1.24 million road traffic deaths occur annually, making road traffic injuries the leading cause of death among people aged 15 to 29 years.

2013: In May, the World Bank releases a report concluding that production of crops for biofuel has only a limited effect on food prices.

2013: On July 3, Asiana Airlines Flight 214 crashed during its approach to San Francisco International Airport. Of the over 300 passengers on board, two died at the scene and 181 were injured.

2014: On March 8, Malaysia Airlines Flight 370, carrying over 200 passengers and 12 flight crewmembers, went missing during a scheduled flight from Kuala Lumpur to Beijing. Despite extensive

searches, as of June 2014, no trace of the plane has been found.

2014: On April 10, the European Commission issues its first-ever EU Transport Scoreboard, comparing member states on 22 categories, including safety, environmental impact, and infrastructure for road, rail, water, and air transportation.

2014: On May 7, the U.S. Department of Transportation issues an Emergency Restriction Prohibition Order requiring rail carriers transporting large amounts of crude oil from the Bakken shale formation to notify counties in each state through which the crude oil will be moved. This requirement was prompted by several accidents

involving the volatile Bakken crude oil, including an explosion in Quebec that killed 47 people.

2014: On June 23, a group of electric car advocates led by the Illinois Green Economy Network begins a 500-mile drive across Illinois to counteract range anxiety (the fear that an electric car will run out of power before reaching a charging station). The drive, which began in Carbondale and ends in Grayslake, includes stops at 11 Illinois community colleges that have charging stations.

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Access Roads

Access roads represent the most fine-grained connections within an urban street network. They generally provide direct, local access to individual lots and feed into the arterial road network. On these bases, development will generally front rather than turn its back on access roads. Access roads generally assume a simple, undivided cross section, with regular lot access and low traffic speeds being primary considerations. These compare to higher order roads that assume more complex geometries, are often wider, and limit direct lot access in favor of higher travel speeds and longer trips.

Access roads feed into these higher order roads (often called distributors or connectors), which span and link adjacent neighborhoods, much like streams feed main tributaries within a river system. These higher order roads, in turn, can feed into the primary or arterial road network, which is typically characterized by higher speed limits, significantly increased carrying capacity, and much less local accessibility. This sort of hierarchical system was embraced in North America and Australasia during the post–World War II boom in road building, motorization, and suburbanization. Elements of this system have also been adopted elsewhere, but historical, less hierarchical street networks are more apparent in geographies such as western Europe, while relatively disorderly transport and

land use planning in many Asian cities has also produced less hierarchical systems.

Form and Function

The width of access roads varies depending on context. However, a functional width of 18 feet (5.5 meters) for two-way and 11 feet (3 meters) for one-way vehicle flows is appropriate. Added width may be required depending on the types of vehicles that will use the road: wider carriageway is necessary in industrial areas. Depending on carriageway width, two-way roads may permit two vehicles traveling in opposite directions to pass. Narrower access roads have to function as yield streets, requiring passing areas. Passing areas are usually facilitated through intermittent gaps in on-street parking.

The use of a road by a particular mode of transport depends on the functional hierarchy, urban location, and land use situated along the road. Access roads are often intended to facilitate use by a variety of transport modes, with particular emphasis on pedestrian activity. It can be expected that more pedestrian activity will occur within residential land use cells (particularly where shops and open space are accessible locally) than within non-residential (that is, industrial) precincts. Despite this expectation of use by pedestrians, many residential access roads have been constructed without footpaths, or sidewalks. This can create difficulties for all potential pedestrians and particular problems



A series of narrow access roads, enhanced by landscaping and several small- and medium-sized roundabouts, surround this shopping center and its parking lot in Málaga in southern Spain. Roundabouts, often seen on busier access roads, may serve dual purposes of both managing vehicle movements on different approaches and fostering traffic calming.

for the mobility and visually impaired. The lack of pedestrian facilities along access roads can reflect low anticipated walking demand.

Aside from footpaths in some circumstances, access roads rarely incorporate specific design responses in support of facilities for pedestrians, cyclists, or public transport. This is because access roads represent the bottom rung in a road hierarchy and, in theory, attract relatively low traffic volumes at relatively slow speeds. Cyclists are expected to use the carriageway, while transit services are more likely to use higher order roads rather than access roads except for short distances. Moreover, the carriageway width and swept paths required by buses can compromise objectives relating to safety and speed mitigation, thereby adding to the case for transit to be routed via higher order roads.

Other Design Characteristics

Depending on their location within the urban fabric and local design prerogatives, access roads

can incorporate additional, nontransport features. Often, service infrastructure (water, sewerage, and power) needs to be accommodated either above or below ground. In newer developments, most services may be located below ground within the road shoulder. However, some older access roads may have service infrastructure located below ground within the roadway, hence the ubiquitous manhole covers that can be found in cities like New York and Paris.

Street furniture in the form of signage, street lighting, and seating are further encumbrances within a typical access road cross section. Highly urbanized areas such as town centers generally reflect a higher density of street furniture compared to a typical residential area.

Soft landscaping is common in residential areas and less so in constrained, highly urbanized environments where space is at a premium. In urbanized areas the landscaping response may be in the form of hard landscaping, such as paving, stone,

and metals. On-street parking provisions may range from parallel curb parking to parking bays depending on cross-section widths and local parking requirements.

Drainage functions may be hard-engineered into street designs through provision of curbside gutters. Alternatively, “soft” drainage infrastructure may be collocated with landscaping in the form of swales.

In short, there is no common design for access roads. Rather, design responses should and typically do support local functional requirements and safety and amenity objectives.

Capacity and Speed

The capacity of an access road is influenced by the posted speed limit, general design characteristics such as road width and geometric characteristics, density of intersections, and lot access spacing. The practical capacity of a typical single carriageway road—two-way and wide enough for two vehicles to pass relatively comfortably—is approximately 15,000 vehicles per day or 1,500 vehicles per hour in the peak.

A much lower threshold can both apply to and be desirable for many access roads, particularly within residential areas. For example, above about 5,000–6,000 vehicles per day, direct lot access becomes difficult to manage (and can be hazardous), especially where vehicles need to back out into the carriageway because of the reduced frequency and generally reduced gaps in traffic along the access road. Under these circumstances, special provisions may be needed to enable protected reversing maneuvers. Moreover, the presence of higher levels of traffic (more than 6,000 vehicles per day) within residential areas generally results in environmental degradation when considered from a noise or vehicle emissions perspective.

Posted speed limits that apply to access roads depend on where they are located within the urban fabric and the land uses they serve. In inner urban and dense residential areas, speed limits of 20–25 miles (30–40 kilometers) per hour may apply. In Australian cities, in suburban locations, a 30 mile (50 kilometer) per hour limit is typical. In outer industrial areas, a slightly higher speed limit (for example, 60 kilometers or 35 miles per hour) may apply. Generally, the speed limit should reflect the density of activity along the access road (including

frequency of property accesses and nonvehicle activity such as walking and cycling).

The design speed limit of a road can vary greatly from the posted speed limit. Generally, the following design elements influence actual travel speeds:

- Lane width
- Midblock pedestrian and bicycle crossings
- Block length
- Provision of on-street parking, given it can create friction along the carriageway
- Landscaping treatments, including how dense they are and whether they are planted up to the curbline
- Development setbacks
- Any vertical or horizontal deflections

In principle, more visually and physically constrained carriageways produce stronger cues for drivers to manage their speeds.

Chicanes, traffic islands, speed tables and the like are typical devices constructed along access roads to deflect vehicles from straight, uninterrupted paths of travel and thereby manage traffic speeds. As isolated treatments, they can also dissuade through traffic from particular routes due to the inconvenience of negotiating them. In many cases they are retrofitted to roads when it becomes evident that traffic speeds and/or flows exceed desirable limits. In extreme circumstances, access-road connections (through roads) may be turned into culs-de-sac to reassign nonlocal traffic on to other more favorable routes.

Intersections

Intersection density along access roads is relatively high, with planning ordinances in many cities stipulating maximum block lengths. This befits access roads being at the bottom of a functional hierarchy of roads.

Intersection treatments can vary depending on the form and function of cross streets. In some cases, there is no regulatory signage, even at four-way junctions. This transfers all responsibility to drivers to negotiate the intersection and, arguably, compels drivers to take care on approach because of the uncertainty of the behavior of other motorists.

Priority control treatments—yield (give way) and stop signage—are common. These typically apply to the minor, less trafficked, approaches, and direct

motorists to yield right of way. At busier intersections, small roundabouts may be installed. These can serve dual purposes: managing vehicle movements on all approaches and acting as a traffic calming device.

It is rare for traffic signals to be constructed on access roads, except where a road intersects with a major (arterial) road, where, without such a treatment, vehicles would have insufficient opportunities to turn into or out of the minor approach or approaches. Often, such a high-order treatment is installed only when there are no alternative routes into an urban area or the access road has some other strategic importance.

The alternative is to restrict movements onto and from the access road through installation of engineering devices such as “seagull islands.” This is to prevent risky turning maneuvers that can evenuate when there are few gaps in traffic and drivers get frustrated. In locations such as Britain, India, Japan, and Australasia, where people drive on the left-hand side of the road, right-turning movements are often banned in these circumstances. In North America, continental Europe, and China, where people drive on the right, left-turning movements are banned.

New Planning Paradigms

Strategies to mitigate and manage traffic speeds and volumes along access roads have strong political and planning bases. Speed management is understandable where there is a high frequency of crossing movements and movements to and from individual lots. Within residential neighborhoods, there can also be significant pedestrian and cycling activity, and roadways can double as spaces for recreation and play. These functions cannot be reconciled with higher traffic densities and speeds.

Nevertheless, the local connectivity and network permeability that should characterize access roads can be undermined where curvilinear street designs, culs-de-sac, and local area traffic management devices are employed to dissuade through traffic and deliberately isolate specific urban cells. Such street designs have been popular in new tract-housing developments in many North American and Australian cities. For example, Radburn-style design promotes disconnected street networks and isolated urban cells and may be explored in detail in Peter Hall’s *Cities of Tomorrow* (2002). These

outcomes can reinforce car dependence and urban sprawl by increasing distances between origins and destinations, thereby reducing opportunities for people to utilize modes of transport other than cars.

Some neotraditional planning movements, such as North American New Urbanism, challenge the road hierarchy concept and decision making that reduces the connectivity of the street network. This is for a variety of reasons, but crucially, New Urbanists posit that a hierarchical design helps reinforce an overemphasis on the needs of private motor vehicle users. A resource that explores these issues is *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream* by Andrés Duany, Elizabeth Plater-Zyberk, and Jeff Speck (2000).

Instead, the neotraditionalist approach focuses on density of connections generally in the form of a grid road-network pattern providing a choice of routes to permit reduced distances between homes, jobs, and other destinations. By implication, the local access and activity functions associated with access roads need to be reconciled with some through-traffic movements so that longer trips are not simply funneled to connectors and arterial roads.

On one hand, this approach has the potential to stimulate more urban vitality and vibrancy, which is a core New Urbanist tenet. However, it also poses a practical challenge to the exclusivity and quiet sought by many residential communities.

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See Also: Accessibility and Mobility; Levels of Service; Livable Streets; Neotraditional Neighborhoods and Transportation Impacts; Road Hierarchy; Street Design/Patterns.

Further Readings

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Accessibility and Mobility

Accessibility and mobility are two of the basic concerns in transportation. Although frequently used as synonymous, these concepts reflect different goals for optimizing travel movement from both a socioeconomic and physical context. These concepts are critical to travel and travel choice, providing useful measures and indicators for analyzing and understanding past and present travel and for shaping future travel. This entry presents a conceptual discussion of the distinction between accessibility and mobility, followed by a description of basic measures and indicators, and a brief overview of recent developments worldwide of mobility and accessibility conditions. Finally, special attention is given to the role of these concepts in policy and planning practice.

Conceptual Discussion

From common spoken language to newspaper articles and even to papers of a more scientific nature, accessibility and mobility are commonly used indiscriminately and even as synonymous. Moreover, one can say that in recent years accessibility has even become a trendy concept in both social and political contexts, with accessibility often preferred over mobility independent of the concept being referred to at the moment. In fact, the term *accessibility* has become very common, being one of those terms almost everyone uses (especially in planning and politics) although clear notions of its meaning or of how to measure it are far less common.

Even though both concepts translate a specific ability related to spatial (or virtual) connectivity, they refer to different, although interconnected, abilities. Looking at plain definitions in common

dictionaries, we find the word *mobility* to be the ability to move and the word *accessibility* to be the ability to access or reach. In other words, mobility represents the ease of movement while accessibility represents the ease of reaching desired destinations (opportunities or activities).

The concept of mobility can easily be operationalized through a number of common indicators measuring if, how, and how much travel is performed. Most common indicators measure travel distance, time, frequency (number of personal or freight trips), and mode choice. In contrast, accessibility is a far more ambiguous notion, implying a range of aspects, such as the distribution of potential destinations; the magnitude, quality, and character of activities; the performance of the transportation system; the characteristics of the individuals; and the times at which the individuals are able to participate in activities, among others. Conceptual discussion around accessibility has been somewhat limited. The multidimensional nature of accessibility justifies why several researchers in this field have advocated that the definition of the concept of accessibility depends on the objective for which it is intended. Most common accessibility measures identify areas in equidistance/time of important destinations such as capital cities, city centers, or major transport nodes (isochrones), catchment areas or market areas of important public services or transport nodes, and number or diversity of activities accessible or utility of that access. For more detail on measures and indicators of accessibility and mobility, see below.

Mobility represents the choices people make, while accessibility represents the choices people have, of which only some will actually be made. In this sense accessibility can be regarded as potential for mobility (in short, potential mobility). In fact, mobility or actual travel behavior is an indicator of accessibility but is not a measure of it; that is, high mobility might be an indication of high accessibility, but it is not possible to measure accessibility based on the amount or form of travel.

Measuring Mobility

Mobility indicators provide measures for travel demand, being generally used to identify travel needs and infrastructure congestion or development needs. As stated in the conceptual discussion, the most common indicators of mobility measure

travel distance, time, frequency (number of trips or cargo), and mode choice.

The collection of data for these measures is generally done by resorting to counting and/or travel behavior surveys. Individual data is then aggregated by socioeconomic/demographic groups, by transport mode, by travel purpose, by travel time (in a day, week, month, or year), etc., to develop the analysis of travel patterns. Thus, the general indicators of travel frequency, distance, and time can be presented in any of the above aggregations.

Mobility planning practice may use any of the above indicators and/or resort to mobility-based planning support instruments such as mobility models, transport models, or even land use and transport models.

Measuring Accessibility

Similar to the conceptual discussion around accessibility and mobility, measuring accessibility is again more complex and a less consolidated research field than mobility. However, the theoretical background already provides some baseline concepts, characteristics, and features for measuring accessibility, such as the following:

- Components
- Types of measures (which some authors call “traditions”)
- Operational choices

Although there is no best measure of accessibility, there is a general understanding on the main components of accessibility measures. Accessibility measures generally consist of two basic parts: the land use component (also named activity, motivational, or attraction component) and the transport component (also named resistance or impedance component). The land use component is related to the supply of opportunities. The transport component, like the land use component, is related to the confrontation between supply and demand, in this case, of the transport system. In addition, two further components may be used in accessibility measures: the temporal and the individual components. The temporal component reflects the times at which individuals are able to participate in activities as well as the availability of opportunities at different times of the day. The individual component reflects the characteristics of the individuals, including the

needs (which are dependent on characteristics such as age, life cycle, and lifestyle), abilities (related to physical capacity and specific skills), and opportunities (related to income and travel budgets), depending on individual characteristics. Information and communications technology (ICT) may be considered as the fifth component (when referring to virtual accessibility). Although all of these components have been deemed relevant by one or another publication in the field of accessibility measure, it is generally recognized that it would be difficult to consider all components at once, since it would imply high levels of complexity. Nonetheless, it is important to recognize the implications of excluding one or more of these components when using accessibility measures.

When developing accessibility-based planning support instruments, several accessibility “traditions” are available in the literature. In general, accessibility instruments may be activity based (measuring activities/opportunities accessible) or utility based (measuring the utility of accessing particular activities/opportunities), may be person based or location based (measuring accessibility of people or of places), and/or may be origin based or destination based (measuring accessibility from origins—people or places—or to destinations—people, opportunities, or places). Accessibility instruments may follow one or a combination of these approaches. They may even combine antagonistic approaches, such as combining measures based on origins and measures based on destinations.

Finally, the development of an operational accessibility measure, able to support planning, involves a number of choices from a list of potential features increasing the scientific rigor of the instrument. The following list summarizes several of the most common options to consider incorporating into accessibility measures currently found in the model-building literature:

- Distance decay (simple activity-based measures not considering distance decay and simply summing activities accessible within a specific time limit are generally called “contour measures” or “isochrones measure” or “cumulative opportunity measures”; simple activity-based measures considering distance decay are generally called “potential measures”)

- Competition effects of origins and/or destinations (simple activity-based measures considering the number of activities of the same type or the size of each establishment in accessibility measures are generally known as “gravity measures”; these measures may or not consider distance decay; another example of measures considering competition effects are “inverse balancing factors”)
- Personal or group preferences/constraints (measures including time constraints include the individual component referred to above)
- Trip purposes (considering one specific trip purpose or all trip purposes aggregated versus developing analysis of accessibility per different trip purposes)
- Transport modes (only one transport mode or all aggregated/integrated choosing fastest/cheapest)
- Times of day or days of week/month (measures including time constraints include the temporal component referred to above)

Measures

Some examples of accessibility measures (basic accessibility measure) are isochrones, contour measures, and potential measures.

Isochrones are curves that are equidistant/time from a given origin or destination. The buffers defined by these isochrones identify the physical space one can reach in a given time or distance limit.

Contour measures count the amount of opportunities one can reach within a given time/distance/price limit (also called cut-off) from an origin or destination. Alternatively, contours measure the distance/time/price required to reach a given amount of opportunities from a given origin or destination. The general formulation used for this measure is as follows:

$$A = jO_j \text{ if } d_{ij} \leq L \quad \text{if } d_{ij} > L$$

with A_i : accessibility at origin i ; O_j : opportunities at destination j ; d_{ij} : distance/time/price between origin i and destination j ; L : accessibility limit (cut-off) measured in distance, time or price.

This measure can be used, for example, to identify the population able to reach a primary schools

within five minutes walking time (which represent the potential users of this school), or to identify the number of schools one can reach within five minutes walking from home (which represent the available choices), and so forth.

Potential measures are similar to contour measures; however, they consider distance decay of the importance of opportunities with distance/time/price. The farther away or more cost in reaching an opportunity, the less the influence of that opportunity in the accessibility measure. The general formulation used for this measure is as follows:

$$A = jO_j * f(d_{ij})$$

with A_i : accessibility at origin i ; O_j : opportunities at destination j ; d_{ij} : distance/time/price between origin i and destination j ; $f(d_{ij})$: distance decay function between the origin i and the destination j .

Conceptually, contour and potential measures are very similar using, however, different distance decay functions.

Accessibility planning practice may use any of the above measures and/or resort to accessibility-based planning support instruments. A Web-based online platform for accessibility-based planning support instruments is available at <http://www.accessibilityplanning.eu/accessibility-instruments-2>. This platform presents a number of accessibility instruments developed for planning support, including detailed descriptions on how to use them in practice. An online search engine is also available, enabling the identification of tools regarding operational requirements. Alternatively, a review can be found in a report by scholars Angela Hull, Cecília Silva, and Luca Bertolini, “Accessibility Instruments for Planning Practice.”

Evolution

Urban mobility has undergone significant changes over the past few decades. When referring to passenger mobility, travel distance and frequency have been increasing and the car has become the main means of travel in most European and North American cities, due to its spatial and temporal flexibility. Cargo has also increased exponentially following globalization, with growth across all main transport means (road, air, and sea). In general, it is fair to say that there has been an unprecedented growth in passenger and freight mobility.

Taking a closer look at passenger mobility, several factors have been found to have contributed to this change in travel behavior. The main factors can be summarized as follows:

- Geographical (urban structure) factors (for example, urbanization, suburbanization, car-oriented development, provision of major transport infrastructures)
- Economic, technological, and political factors (for example, globalization, gross domestic product growth, increase of income per capita, cheaper and faster transport modes, increasingly diversified and flexible employment)
- Sociodemographic and cultural factors (for example, increase of population, especially urban population; aging population with better life conditions; change of the role of women in society; smaller households; increase of number of households; rising living standards)

The development of faster and cheaper transport modes has enabled the enlargement of urban areas (urban sprawl) with higher dispersion of households and opportunities, which has, in return, made people more dependent on the car to satisfy daily mobility requirements. The general increase of wealth and income associated with decreasing working hours has enlarged mobility requirements especially for nonwork activities. The rate of work-related trips has decreased considerably, with commuting representing less than half of all journeys in many European and North American countries. Within nonwork trips, which have become the most frequent in large urban areas, leisure trips present the highest travel distance.

While fewer working hours have contributed to more leisure time, social changes have stimulated out-of-home leisure activities, which have been diversifying and therefore contributing to the complexity of travel patterns, which requires higher flexibility from urban transport modes. The household has also experienced many changes, with women having full-time jobs, therefore having fewer children, which are also born later because people tend to marry later in their lives. The whole family has a different structure, higher incomes, and more spare time, which they use for ever-growing

extra activities. Consequently, mobility needs continue to rise and to become more complex due to new travel patterns and extensive urban areas. The travel purposes are less predictable, and those that still are, are losing their share. The private car has been found to provide the required standards (for example, flexibility, accessibility, low cost relative to public transport, high speed) within the contextual change referred to above, having become the dominant travel mode in almost every urban area around the world.

However, increased mobility is not synonymous with increased accessibility. Today, we travel for longer distances than before to reach the same activities. It is true that we have more choices for the same activities, but the variety of activities accessible had but a marginal growth. At the same time, automobile-based mobility has significantly changed our cities as well as the offer of alternative modes. Cities have spread, with a first wave of decentralization of households closely followed by the decentralization of activities. Ever-growing decentralization, enabled by the generalized use of the private car and accelerated road infrastructure provision, has gone well beyond the ability for activity decentralization.

While public and private activities tended to follow urban development (the latter accompanied by public transport expansions and coverage), this is no longer the case. On one hand, low-density development does not provide a competitive market for the development of activities. On the other hand, increased regional accessibility by car still enables businesses to reach dispersed communities without having to move to the neighborhood. Adding to this, public expenditure reductions (due to budget constraints) have also led to concentration of public services using regional car accessibility as grounds for decreasing local service levels.

Regarding supply of transport modes, it is fair to say that public transport has generally improved; however, road infrastructure improvements have, for a long period, been the major political priority. Thus, public transport has been mainly regarded as an alternative for those economically or physically excluded from using the car. There has been a lack of a real comprehensive approach to alternative transport service provision.

As a result of all the phenomena discussed above, increased mobility has, in several cases, also been

responsible for reduced accessibility. For instance, when people with limited access to cars become more distant from desired activities that have decentralized to car-accessible zones, while no alternative public transport modes have been offered or made available, public transport does not provide desired quality standards (regarding comfort, safety, reliability, physical barriers, etc.).

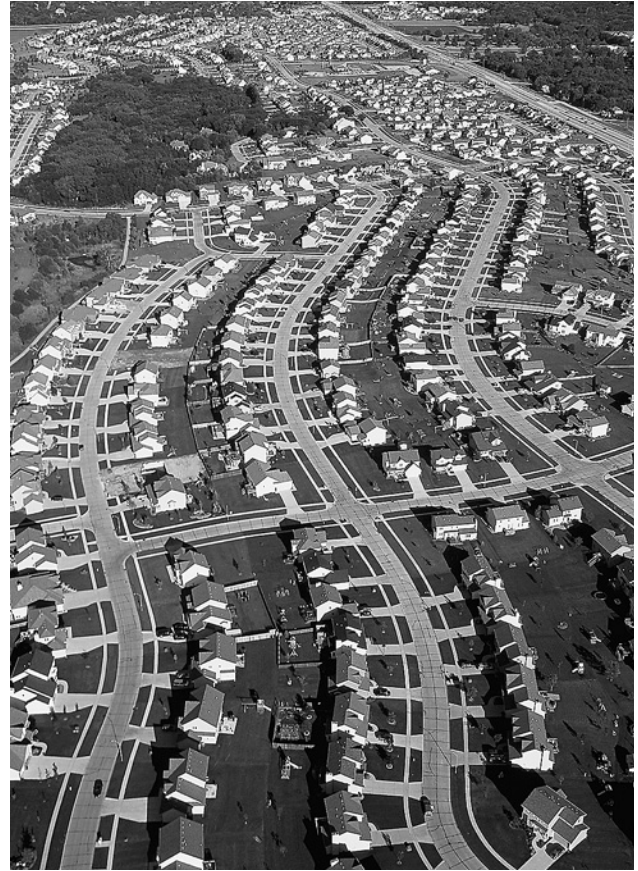
In fact, international and regional accessibility levels have been growing over time due to cheaper and easier medium- and long-distance travel enabled by the car and the plane. However, local accessibility has decreased in several urban areas. This has been the result of low-density, monofunctional urban developments (creating neighborhoods with low local accessibility) in addition to the phenomena of concentration of activities in major regional shopping or retail centers while gradually leaving local communities (decreasing local accessibility in former high-accessibility neighborhoods).

In summary, accessibility losses have been mainly brought about by decreased competitiveness of public transport services (in comparison to car) and by the decreasing availability of local activities (either because it is not economically viable to move activities to low-density development or because it is less economically viable to stay in high-density local neighborhoods than to move to regional shopping centers). In addition, other phenomena, such as traffic congestion, have also decreased accessibility (even car accessibility) while transport infrastructure developments have managed to increase road mobility.

Planning Support

Urban, regional, and national planning. Accessibility and mobility are key factors in the understanding of real and potential flows, interactions, and interdependencies at the urban, regional, and international levels. In terms of economic development, mobility and GDP growth are believed to be directly connected. Current trends argue for a decoupling of GDP and mobility growth and for finding new ways to achieve economic development without increased mobility.

As described above, mobility has been growing, following urbanization and decentralization phenomena of urban areas, making mobility one of the key issues in urban and regional planning but also at the international level. More recently, accessibility



A residential development with a road network emphasizing private car travel over public transport seen near Des Moines, Iowa, in 2011. Such regional car accessibility may be used as grounds for decreasing local public transport service levels.

has also been recognized as a key planning issue, with access being acknowledged as the main planning concern. The primary need of people, and of freight, is to reach desired destinations and activities and not mobility itself. Regardless, the balance between demand and supply of mobility needs is still a key issue in planning. Nevertheless, recent trends have emerged, arguing the need to manage travel by reducing unnecessary travel and making necessary travel more sustainable. These new trends have questioned one of the basic mobility principles—that travel demand is derived.

Planning for mobility versus planning for accessibility. In urban and regional planning, several voices have been raised in favor of a paradigm shift from mobility-based planning to accessibility-based planning. While mobility-based planning holds

mobility and its improvement as its main concern, accessibility-based planning shifts the concern from mobility to accessibility and thus from the ease of movement to the ease to reach desired activities. In practice, while the former planning system favors increasing mobility following the “predict and provide” paradigm (and, in some cases, even provide without predict), planning for accessibility recenters urban and transport planning on the connection of people and activities. Thus, mobility-based planning centers on infrastructure provision and performance while accessibility-based planning looks at travel from a more holistic perspective, considering infrastructure, land use, spatial distribution of opportunities, livable streets, etc., at the same time that it enables comparative analyses of competitiveness of different transport modes. Finally, this paradigm shift results in a shift of focus from the means (infrastructure and its performance) to the ends (fulfillment of people’s expectations).

Transport planners following the traditional “predict and provide” paradigm will say that when they are planning for mobility they are also planning for accessibility: that their aim is to fulfill people’s expectations. This understanding resides on the assumption that all demand is derived from physically dispersed activities and thus, when supplying solutions for demand, accessibility and expectations are also being supplied. However, when planning for mobility and defining demand based on mobility indicators, these are not measuring travel choices available but real travel choices made. Thus, the supply of solutions will favor solving mobility problems (which may increase accessibility, although mainly car and regional accessibility) but not necessarily accessibility problems of all people (especially, car non-users). This means fulfilling peoples’ increased travel requirements instead of fulfilling lifestyle needs. The latter do not include more mobility but refer mainly to the need to reach desired opportunities, if possible, with less travel and with less expenditure. Using only mobility indicators provides planners a limited view on travel needs and on “people’s expectations.”

While traditional transport planning considers mobility to be derived demand, recent research has suggested the existence of other forms of demand, such as induced and latent demand. A basic definition of these concepts describes induced demand

as increased demand resulting of the increased supply (improvement of mobility conditions), and latent demand as potential for increased demand that would be produced by the increased supply. For example, building a new motorway may relieve congestion on main roads, but in the long run, demand may increase more quickly than expected because more people move close to this highway in search of better and cheaper housing with easier access to the city center (induced demand), or because people already living near the new motorway who before never considered commuting to the city center are now able to (latent demand). The latter case is a clear example to how improved infrastructure can generate new travel needs that were not present before and that now become needs and even new rights.

In addition to these alternative forms of demand, recent research has also suggested the existence of undirected and excess travel. Undirected travel is trips made without the purpose to participate in any activity at the destination (or where the activity is a secondary objective), while excess travel is trips with distance, time, or route exceeding the minimum required to access the destination (for example, taking the longer way home to avoid congestion even if it takes the same time).

Conclusion

While both mobility and accessibility are key issues in urban, regional, and international planning, planning should be based on accessibility concerns offering a more holistic perspective on travel, urban development, and people. This will, first and utmost, require dissolving the conceptual mismatch between accessibility and mobility and breaking the traditional approach regarding derived demand.

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See Also: Derived Demand; Gravity Models; Induced Travel; Integrated Transportation and Urban Land Use Planning Models; Latent Travel Demand; Urban Sprawl Versus Compact Development; Urban Transportation Modeling System.

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significant advantages over traditional trip-based models, usually based on a four-step paradigm, in explaining travel behavior and response to policies.

The growing complexity in travel patterns and the need to estimate changes in travel behavior in response to new policies and advanced technology call for a better understanding of such issues as the effects of new information and communication technologies on travel behavior, the effects of land use and growth management on travel behavior, and travelers' response to auto-restraining policies. Understanding such effects, which is essential for an improvement in the design of new policies, is the main motivation behind the development and advancement of activity-based models.

The basic notions of activity-based demand analysis and modeling can be found in the contribution of researchers T. Hägerstrand and F. S. Chapin, who postulate that the activity demand is motivated by basic human desires, such as the desire for survival, social encounters, and ego gratification. Hägerstrand's time geography theory focuses on personal and social constraints when explaining our need for activity participation, while Chapin focuses more on opportunities and choices rather than the constraints.

In activity-based modeling the basic travel unit is a tour defined as the sequence of trip segments that start at home and end at home. Some simplified versions of activity-based models, referred to as tour-based modeling, deal directly with tours without deriving them from the daily activity pattern as done in activity-based models. The explicit modeling of activities and the consequent tours and trips enable a more credible analysis of the responses to policies and of the subsequent effects of policies on traffic and air quality.

The rich spectrum of issues that activity-based models can account for include travel behavior changes in response to activity timing modifications, for example, flexible working hours and opening hours of stores; the impact of various land use policies on shifting activity patterns, such as mixed-use development, that increase walkable access to various activities; and the ability to consider the trade-off between out-of-home and in-home activities. This latter feature is very important in analyzing the effect of technology advancement and Internet services on substituting out-of-home activities requiring travel with in-home activities.

Accident Avoidance Systems

See Automobile Accident Avoidance Systems

Activity-Based Models

Activity-based models are the new generation of travel demand models. Activity-based modeling treats travel as being derived from the demand for personal activities. Travel decisions, therefore, become part of a broader activity scheduling process based on modeling the demand for activities rather than merely trips. These models have

One of the main factors for the improved behavioral realism of activity-based models is their ability to consider the secondary effects of policies. Secondary effects are those adjustments to an activity pattern that are made in response to a primary impact. For example, a transit subsidy may result in a commuter changing the mode of travel for the trip between home and work from drive alone to transit; this is the primary effect of the policy. However, because the person no longer drives to work, it is not possible to stop on the way home to buy groceries. Therefore, when the person now returns home by transit, it is now necessary to take the car and drive to a nearby store. This is the secondary effect.

In such cases, the advantages of the policy may be at least partially offset with the reduction of the work auto trips being replaced by a new shopping auto trip. Activity-based modeling provides a unique insight to such secondary effects.

Another advantage of the activity-based model system is its ability to better consider induced travel and specifically the generation of new trips as a result of transportation improvement as well as trade-offs among different travel behavior decisions. In the four-step model, there are usually no level-of-service variables in the trip generation model, and therefore the model cannot account for generated travel. In the disaggregate activity-based model system, accessibility variables are fed from each level to the level above it and, in this way, changes in level of service by new or improved transportation infrastructure can change not only the mode or destination of travel but also the amount of travel.

The linkages between all the model levels allow for trade-offs between all levels of travel decisions, including between different types of tours. This is a significant improvement over the four-step model in which each trip purpose is analyzed independently from other trip purposes.

Approaches

A variety of research methods have been used to study activity behavior, including duration analysis, limited dependent-variable models, structural equation models, and computational processes models. Different approaches have been used for activity-based models but they usually take one of two main approaches: discrete choice analysis

(DCA) and rule-based process. Based on the DCA approach, scholar Moshe Ben-Akiva and colleagues proposed a practical activity-based, comprehensive, travel-demand modeling framework that captures the mobility, activity, and travel decisions of individuals and households. In addition, a corresponding prototype system of models that can be used for planning and policy analysis was developed by researchers John Bowman and Ben-Akiva. Applications have followed and have been demonstrated for policy analysis by Yoram Shiftan and John Suhrbier.

Some early applications of activity-based models include R. Kitamura and colleagues, who used a dynamic and integrated microsimulation forecasting approach to test transportation demand management (TDM) in the Washington, D.C., area. Other attempts to forecast behavioral changes to transportation policies using an activity-based approach include researcher Patrick Bonnel's in 1995, the STARCHILD model by W. Recker and colleagues in 1986, and the SCHEDULER model by T. Garling and colleagues in 1994.

Today, most advanced metropolitan transportation planning agencies that develop a new travel demand model are developing an activity-based model. Fully developed and applied examples of such models can be found in Portland METRO, the San Francisco County Transportation Authority (SFCTA), the New York Metropolitan Planning Council (NYMTC), the Mid-Ohio Regional Planning Commission (MORPC), and in Tel-Aviv, Israel.

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See Also: Microsimulation Models; Transportation Planning; Travel Modeling; Urban Transportation Modeling System.

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Adopt-a-Highway Program

Adopt-a-Highway has been an important economical and citizen stewardship concept that has saved U.S. states countless dollars and improved the travel environment immeasurably. The idea came about in 1984, when James R. “Bobby” Evans of the Texas Department of Transportation (TxDot) noticed some debris had flown off a passing truck and then onto the road. The citizens’ pickup concept was actually initiated by Billy Black, a public information officer for TxDot, within his Tyler District. Recognizing the fact that the cost of litter pickup was going up 15 to 20 percent a year, the cause for litter pickup needed to be promoted. This would include safety training, the wearing of reflective vests, and other equipment as needed. The Tyler Civitan Club was the first group to “adopt” a highway, cleaning off litter from a stretch along Highway 69. A plaque recognizing their first Adopt-a-Highway efforts was placed on March 9, 1985. There are now thousands of Adopt-a-Highway groups in America and other places, such as Puerto Rico, Canada, New Zealand, and Japan. Every March 9 is now observed as International Adopt-a-Highway Day.

Funding and Program Provisions

Each state, according to its size, budgeting organization categories, and unique concerns, handles the Adopt-a-Highway program a little bit differently. In Arizona, for example, the program is funded by the Intermodal Transportation Division (ITD). The ITD oversees the maintenance of the state’s highway system, with the majority of its funds coming from the Highway User Resource Fund (HURF). The HURF funds the equipment and instructional materials for Adopt-a-Highway through gasoline and fuel use taxes, as well as vehicle license taxes, car registration fees, and other miscellaneous state fees. Other states also put Adopt-a-Highway resources into their respective budgets.

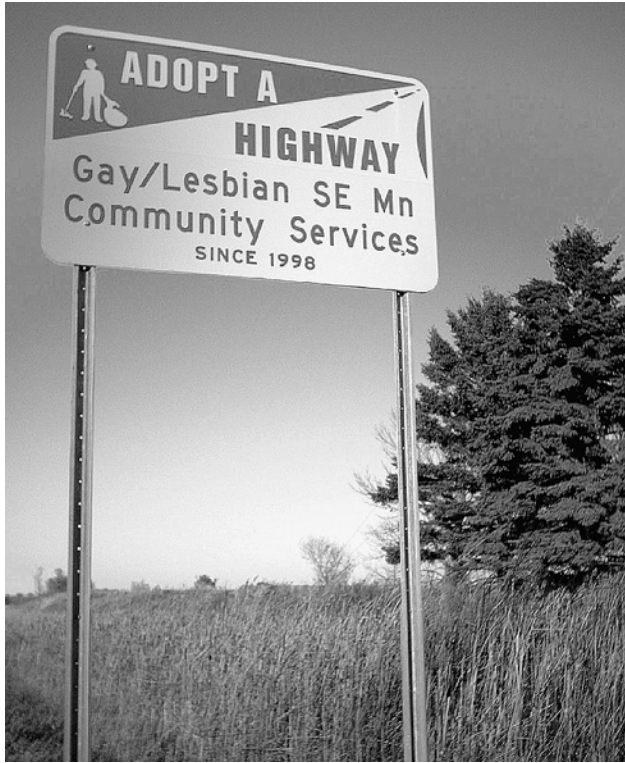
Primary sources of litter in all states are motorists who do not use ashtrays or trash bags in the car but instead toss the garbage onto the highway. Litter may also come from trash containers that have not been properly closed, causing the debris to fly out and land on or beside the highway. Trucks with either unsecured or uncovered loads are at risk of

losing some material to the roadside. And some pedestrians and cyclists passing through on roads other than the interstate highway may toss litter as they go along.

Age and other limitation requirements can also vary from state to state. In some states, adult citizens and minors aged 12 to 17 can volunteer for Adopt-a-Highway, but the minors must be supervised by an adult who is at least 21 and must also submit a youth participation release form to the program. In others states, like California, volunteers can be aged 16 and older, with minors supervised by an adult. The programs must not discriminate based on ethnic origin, race, sex, color or political affiliation. This was put to the test in the state of Missouri when the Ku Klux Klan (KKK), a white supremacist group, tried to get a sign put up acknowledging their work along the highway in Missouri. The State of Missouri refused; the KKK argued that this violated their First Amendment rights to free speech. The case was decided by the U.S. Supreme Court, which ruled in 2005 that the state could not prevent the KKK from participating in the Adopt-a-Highway program.

In California’s Adopt-a-Highway program, handled by the California Department of Transportation (Caltrans), groups have the option not only to adopt multiple sites to maintain but also to assist with vegetation control for environmentally sensitive areas and to plant wildflowers. Caltrans’s rule is that litter removal statewide be done a minimum of six times a year or the length of time it takes for a significant amount of litter to accumulate at the site adopted. If litter adoption is done near a structure like a bridge and there is graffiti, the group or individuals assigned have the option to clean up the graffiti as well. Graffiti removal turnaround time is shorter than litter pickup, and highly visible structures are assigned to be cleaned in less time—almost immediately if the graffiti is considered to be obscene in nature.

For a state the size of California, trash control is a huge enterprise. In 2012 Caltrans spent \$52 million on highway litter removal, including enough trash and litter to fill 10,000 garbage trucks. By mid-2013 Caltrans picked up and hauled away 2,500 cubic yards of trash and sweep nearly 100 tons of debris off state highways, and removed 16,000 square feet of graffiti, with the help of the Adopt-a-Highway program.



An Adopt-a-Highway sign sponsored by a gay and lesbian service organization on Interstate 90 in Minnesota in 2006. In 2005, the U.S. Supreme Court ruled that freedom of speech prevented groups from being selectively banned from the program.

In another very populous state with a big budget, New York, the Adopt-a-Highway program has also been utilized to help keep down state budget expenses. In the late 1980s, the New York State Department of Transportation decided to reassess its priorities when examining the effects of a declining workforce resulting from efforts to save money. With road issues such as maintaining pavements and removing snow and ice, and budget constraints in mind, the Adopt-a-Highway program was initiated. Today, approximately 5,000 miles of New York state highway have been adopted for cleanup.

Special Programs and Recognition

Many states, even those with volunteers to pick up litter in their communities, also utilize inmate or parolee labor to assist them in hauling trash. In order to initiate this program, city or county governments provide manuals with specific instructions on utilizing inmate labor to clean and maintain highways in selected areas of the state. This

special litter program requires inmates to pick up trash, prune trees, perform hand mowing, or cut down brush; in rural areas, they may also clean out culverts. Not every inmate may be entrusted with this task; inmates assigned to these programs are classified as “trustys,” meaning they have not been convicted of a serious crime, which would classify them as a flight risk. In 2009, in Virginia alone, volunteers and inmates contributed their own time to help the state and picked up 26,300 bags of trash along 1,900 miles of highway.

In California, the Caltrans Parolee Program, established in 2009, provides those on parole three months of employment when they leave prison, and it is said to reduce recidivism rates. Since 2009 parolees have removed 50,000 cubic yards of highway litter, an amount equal to 31,000 filled garbage trucks.

The Adopt-a-Highway program saves states many thousands of dollars a year. One of the biggest efforts in the country is in North Carolina, where volunteers have recently saved the state as much as \$4 million a year. With 125,000 volunteers, North Carolina has a very high percentage of participation. These volunteers clean up 12,000 miles of state maintained roads, with 59 local Adopt-a-Highway (AAH) coordinators overseeing their efforts and providing materials. In 2008 citizens picking up trash for the state of Arizona also provided a “statewide labor benefit” totaling \$4 million.

Businesses can assist this antilitter program to advance their entrepreneurial efforts and encourage their employees to be good citizens; a few Internet-based companies specially advertise how they can assist businesses to improve their image by adopting a highway. Businesses have the option of offering to clean up an area of roadside, post a sponsoring sign, and pay someone a service fee to clean it, or they can encourage participation among their employees. In 2009, ConocoPhillips, an energy company based in Houston, Texas, contributed \$70 million to charity, with \$25 million for funding community investment projects like Adopt-a-Highway. With Adopt-a-Highway, Conoco became creative by promoting the Employee Volunteer Grant Program—a national program that enables employees to apply for grants ranging from \$500 to \$3,000 for capital projects or planning projects, with the employees volunteering their time. This special grant program has helped promote environmental responsibility

and awareness among participants who apply for special projects, including those in the Adopt-a-Highway program.

ConocoPhillips and other businesses have strongly encouraged both current employees and retirees to become involved in Adopt-a-Highway as a way to provide a better quality of life in their respective communities. Many transportation departments also present awards to those who participate. In South Carolina, for example, yearly “Pee Dee” awards are handed out for outstanding service by Adopt-a-Highway volunteers or coordinators. With this kind of promotion, the litter pickup becomes a more desirable activity to engage in, and the communities and state both benefit.

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See Also: Environmental Impacts; Green Transportation; Highway and Road Safety; Highway Construction and Maintenance Highway Landscaping.

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Advanced Traveler Information Systems

In recent years, increasing attention has been paid to the development of various applications of Intelligent Transportation Systems (ITS), which are credited with the amelioration of traffic conditions in urban and regional environments. Advanced Traveler Information Systems (ATIS) constitute an important element of ITS by providing potential drivers with information on the network’s current performance both en route and pretrip.

Since information concerning road network conditions and route alternatives is generally either limited or unreliable to the majority of travelers, their choices are often poor, leading to a total increase in distance and/or time traveled. The key principle behind the successful operation of ATIS is that the more informed a driver is (in terms of quantity and quality), the more likely he or she is to avoid forming a false perception and expectation of traffic conditions. In this way, ATIS manages to facilitate travelers’ choices and maximize the utilization of the infrastructure’s capacity. In the long run, ATIS may reduce the need for constructing additional infrastructure due to higher traffic throughput but may also induce additional demand for travel. Regarding society as a whole, given that a considerable number of travelers use ATIS, there will be significant reductions in travel time, fuel consumption, and emissions.

Research on traveler information services sparked in the 1950s and has evolved ever since. The primary objectives for providing travelers with information, however, still remain unchanged, namely, efficient management of traffic, improved traffic safety, and overall enhanced driving operations. Although the first efforts toward the development of ATIS, both in and out of the vehicle (in the form of visual displays informing drivers about upcoming weather conditions) date back to the 1970s, it was not until a decade later that the role of ATIS in the mitigation of the impacts of congestion was stressed. Their primary contribution was to affect en route and pretrip travel choices (departure time, trip destination, route choice, mode choice) and thus maximize the utilization of the available capacity provided by the road network. By the end of the 1980s, the first variable message signs (VMS) were introduced in the United States, informing and advising drivers on possible diversion routes. With emphasis on real-time traffic management, ATIS were further developed and refined during the 1990s as a result of advances in computer and communication technologies.

In the last decade, the philosophy of ATIS has changed significantly so as to encompass a “two-way communication system,” where travelers can interact with the systems, rather than be solely receivers of information. This interaction is facilitated through multilingual visual and auditory interfaces. Moreover, travelers do not only have the

possibility of personalizing the provision of travel information (as they can receive individual routing and travel assistance information based on various criteria—time, distance, cost, etc.), but they themselves also act as transmitters of information.

The ongoing era of development of ATIS is also characterized by a change in what traveler information is and how it is disseminated. Information concerning real-time traffic conditions or routing directions is now enriched, including data on major traveler attractions (theaters, hotels, malls) that travelers might use. For example, there is the possibility for an ATIS to locate and direct a traveler to the nearest restaurant within a radius of 10 minutes' travel time.

In addition, while initial ATIS included VMS and highway advisory radio (HAR), later systems include smartphones, the Internet, in-vehicle motorist services information systems (IMSIS), in-vehicle safety advisory and warning systems (IVSAWS), in-vehicle signing information systems (ISIS), and commercial vehicle operations (CVO) specific functions and in-vehicle dynamic route guidance systems (IVRGS). The latter have the ability to provide routing directions based on prevailing and/or forecast traffic conditions.

Considerations

Due to the fact that ATIS rely on the availability and quality of the data they process, they are accompanied by a series of considerations in regard to their overall functionality and efficiency.

Safety issues associated with the extended use of ATIS, when travelers pay excessive attention to their interaction with the system and eventually become distracted from traffic conditions, are a very important aspect. Recent field experiments showed that travelers respond better to hazard warnings and control their vehicle's direction and speed faster when ATIS are equipped with visual and aural displays.

Market penetration, defined as the proportion of ATIS-equipped vehicles (travelers), is also becoming an important issue, as several studies reveal that there is an optimal number of informed travelers, which, if exceeded, may decrease the overall performance of the network.

Time savings due to the use of ATIS are greatest when a network is saturated (traffic reaches capacity limits), rather than when traffic is lower than

capacity, oversaturated, or incident-free. In the latter cases, route guidance has limited impacts on time savings, thus the trade-off between ATIS cost and perceived benefits may tempt fewer travelers to invest in such systems.

The impacts of ATIS highly depend on how travelers respond to such systems. In this sense compliance with these systems, in regard to the extent travelers follow the provided advice and directions, is directly connected to travelers' confidence in the received information. Should this confidence fail, then the expected benefits in terms of travel time reductions will not be realized. In addition, user friendliness of ATIS is a decisive criterion for travelers to opt for such systems, as they expect a consistent and reliable way of interacting with their in-vehicle devices. Interest is therefore now focused on the overall benefit evaluation of ATIS in order to fully identify the opportunities and risks associated with such technologies. For that reason, various laboratory experiments and field deployments are conducted in that direction, along with the development of mathematical and computer simulation models.

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See Also: Electronic Route Guidance Systems; Intelligent Transportation Systems; Network Modeling; Road Signage; Traffic Monitoring; Transportation Modeling and Planning Software.

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Aerial Tramways

An aerial tramway is a transportation system that uses one or two carriers, or vehicles, suspended from fixed cables while a third cable, called the haulage rope, powered by electricity, provides propulsion. The carriers shuttle back and forth between two end terminals. In jig-back systems, the two carriers always move in opposition to each other. Dual-shuttle tramways use two separate rope loops that allow the carriers to operate independently of each other. Carriers used to move material may be as simple as open buckets, but those used to transport people are enclosed cabins that can accommodate as many as 200 people. Intermediate structures, or towers, support track and haulage cables between terminals. Aerial tramways should not be confused with gondola systems, which use multiple small carriers that circulate along a single cable.

The earliest tramways in the United States were used in mining, but they began to be used to transport people when Americans with more leisure time at their disposal developed an increased interest in skiing and sightseeing in the 1920s. Mining tramways gradually fell into disuse, but aerial tramways began to be constructed in recreational areas. In the late 20th century, city planners realized that the ability of aerial tramways to negotiate natural barriers such as mountains and bodies of water at a relatively low cost could be utilized in urban transit.

Mining Tramways

By the 17th century, primitive forms of the aerial tramway existed in Europe, South America, and Africa, but it was not until the early 19th century when wire rope became available that the potential to use aerial cables to transport freight and

materials was realized. Peter Cooper, an American industrialist and inventor, was among the first to construct tramways for such a purpose. Around 1853, he designed and constructed tramways to carry iron ore to the top of blast furnaces at two sites in New Jersey, but it was the mining boom in the west after the Civil War that brought the aerial tramway into common use.

English inventor Charles Hodgson constructed the first aerial mine tramway in the west in 1871 in the White Pine Mining District of Nevada. The tramway he erected at Treasure Hill, Nevada, transported about 125 tons of ore a day. The tramway constructed in 1872 at the Morning Star Mine about 80 miles south of the White Pine District by Andrew S. Hallidie, wire rope manufacturer and suspension bridge builder, was said to have delivered 10 tons of ore per hour. Hallidie dominated the early period, but competitors were challenging his position by the mid-1880s. By the end of the 19th century, a hundred or more single-rope aerial tramways had been constructed from Juneau, Alaska, to southern Arizona. Mining tramways continued to be constructed as late as the 1950s, but after 1920 low metal prices forced many mines to close. Mines began switching to trucks or conveyor systems, and it was left for recreational use to write the next chapter in the history of aerial tramways.

Tramways in Parks and Resorts

Alexander Bright, a member of the U.S. Olympic Ski Team in 1933, observed the passenger tramways in use in Europe and thought the technology could be used to develop skiing and tourism generally in the White Mountains of New Hampshire. Environmental concerns dictated the choice of Cannon Mountain as the ideal site, as the tramway could be constructed on public land with minimal deforestation. In June 1937, the New Hampshire legislature authorized a \$250,000 bond issue to finance the tramway, and the first passenger aerial tramway in the United States began operation one year later. The tramway carried 163,000 passengers in its first year of operation and more than 6.5 million passengers by the time it was replaced in 1980.

Despite the success of the tramway at Cannon Mountain, chairlifts were cheaper and thus favored in most skiing areas. It was not until the 1960s that aerial trams began to be built with some frequency throughout the United States. The idea of a tramway

in Palm Springs, California, was conceived in 1935, but political jockeying and World War II prevented its construction. Money was raised through private revenue bonds to fund the project, but the Korean War caused more delays. Finally, in 1961, construction began. The tramway was completed in 1963 and designated a historical civil engineering landmark 20 years later. In 2000, renovations made the tramway the world's largest rotating tramway. Delays also hampered the construction of an aerial tramway in Stone Mountain, Georgia. First proposed in the 1950s, it was not until 1962, four years after the state of Georgia bought the land for a park, that the tram began operations. A 25-passenger tram at Heavenly Ski Resort, South Lake Tahoe, California—at that time the largest in the nation—also opened in 1962.

By the end of the 1960s, aerial tramways were operating from Sandia Park, Albuquerque, New Mexico, to Jay Peak Resort, Jay, Vermont. The next decade saw aerial tramways constructed at Pipestem

Resort State Park, West Virginia; Snowbird, Utah; and Gatlinburg, Tennessee. As late as the 1990s, aerial tramways were constructed, including the Mount Roberts Tramway in Juneau, Alaska.

Mass Transit Tramways

In 1976, the first aerial tramway to be used for mass transit was constructed. Originally intended as a temporary measure to solve the problem of lengthy commuter trips with frequent transfer between Manhattan and New York City's Roosevelt Island, the tram proved so popular that it was continued even after a subway station was completed in 1989. The total cost of the system was \$6.25 million; in 2013, the equivalent cost would be more than \$25 million. The tram was closed in 2006 for renovations after passengers were stranded for seven hours on April 18, 2006. Since the tramway reopened in September that same year, the number of daily passengers has increased to an average of 3,750.

In 1999, Portland, Oregon, concluded that an aerial tramway offered the most efficient means of a reliable and rapid transit connection between the Oregon Health and Science University's expanded campus and the waterfront. Construction of the Portland Aerial Tramway began in August 2005; the tram opened to the public on January 27, 2007. The total cost was \$57 million, more than triple the original estimate. Experts predicted that the tram would carry more than 1,500 people daily. The estimate proved modest—1 million passengers rode the tram in its first 10.5 months of operation.

The Future of Aerial Tramways

Economically and environmentally, the increased use of aerial tramways as one solution to the transit problems of urban areas holds great promise. Tram systems can be constructed for only a fraction of the cost of subway lines or light rail. Aerial tramways also have a much more limited environmental footprint than do other modes of mass transit. Trams are energy efficient, and emission rates are low. The systems also negotiate natural barriers without significant topographical changes, and because they are not limited to existing roadways, they cut travel time.

Current technology does not lend itself to the integration of multiple tram systems, and integration into existing transit systems can present challenges as well. Limited capacity and speed mean that the trams cannot equal the capacities of light



New York City's Roosevelt Island aerial tram approaching the Manhattan station in March 2006, the month before a power failure left nearly 70 passengers stranded for seven hours.

rail and bus rapid transit. Additionally, privacy may be a concern when the carriers move over private property. Despite these disadvantages, urban planners in increasing numbers are considering them as an alternative strategy for cities where conventional transit options are limited.

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See Also: Cable Cars; Light Rail Transit; Tramways; Transit Planning, International; Trolleybuses.

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Aeronautical Decision Making

Aeronautical decision making (ADM) is a decision-making system used by pilots and flight crews, with the goal of minimizing accidents and following procedures of maximum safety. The official definition given in the Federal Aviation Administration (FAA) document AC 60-22, which introduces the FAA's guidelines for ADM, is "a systematic approach to the mental process of evaluating a given set of circumstances and determining the best course of action." Most avoidable aircraft accidents are the result not of equipment failure but of pilot error, and the chain of events leading to these accidents is called the error chain or bad judgment chain, which ADM is intended to break. ADM takes the knowledge acquired in primary flight training, especially pertaining to maneuvering in and responding to weather conditions and strong winds, and applies it to the understanding and avoidance of potential hazards. Many of these decisions must be weighed

according to the conditions of the flight, which include not only ambient circumstances like the weather but also the pilot's understanding of his or her own ability and experience, and the design limitations of the aircraft. The best decision in one aircraft is not necessarily the best decision in another aircraft in identical circumstances; likewise, the best decision for one pilot is not necessarily the best decision for another pilot in identical circumstances. Ideally, ADM involves making flight decisions that avoid the circumstances, such as low fuel reserves, necessitating the most difficult decisions. Situational awareness and competent risk management are key.

Remaining aware of and responding to circumstances appropriately may mean avoiding certain situations entirely. Many aviation accidents involve small craft, which do not require pilots of the same experience and skill as pilots of large commercial aircraft, and the most important decision a pilot who is limited in skill or experience can make is to land the aircraft rather than continue in uncertain or dangerous conditions. For instance, the FAA's regulations differentiate between visual flight rules (VFR), which govern flight in weather conditions clear enough for the pilot to see where he is going, and instrument flight rules (IFR), in which the aircraft's instruments provide the necessary information that the naked eye cannot due to weather. Most flights in class A airspace, where jets spend most of their flight time, are IFR flights. Because of the weather conditions that prevail at high altitudes. All such pilots are instrument rated, meaning they have received additional training and experience specific to IFR flights, as well as relevant instruction in meteorology.

The pilot license or commercial pilot license of pilots of smaller craft does not require instrument rating, and one of the most dangerous decisions such a pilot can make is to continue into IFR conditions, when weather has occluded visibility, without being instrument rated. Many aircraft accidents occur when this is unavoidable, which is one reason flights are grounded at times of imminent heavy weather. Further, the transition from VFR to IFR is more stressful and difficult than many non-instrument-rated pilots or even inexperienced instrument-rated pilots may realize, and switching from visual cues to instrument readings frequently disorients the pilot—which is especially dangerous

when the switch is in response to unplanned circumstances. Similarly, the desire to avoid the transition to IFR because one is not instrument rated or is more comfortable with VFR, while also avoiding turning around or terminating the flight, can lead pilots to continue VFR even when visibility conditions have degraded beyond the point of safety. The FAA's rules list specific requirements of visibility and weather conditions for VFR, but a determined pilot may end up "scud running": straining to keep the terrain visible without flying too close to it.

Though some accidents are caused by irresponsible decisions, such as flying too low or attempting aerobatics, a great many accidents occur when the risks are less obvious. The most basic decision is whether to fly at all, and once in the air, whether to continue. The "go or no go" choice is clear when the weather is not: few pilots have trouble deciding to cancel a flight during bad weather. When conditions are more borderline, however, pressures may mount to go ahead with the flight, including the wishes of the passengers, any payment involved in the flight, an appointment or other pressing need to be at the destination by a certain time, and the simple human desire to continue on with the plan in motion. Every flight should be approached with the understanding that it should be undertaken only if the risks are justified by the skill of the pilot and the design limitations of the aircraft. This does not mean flying only when conditions are perfect, but every pilot's plan should include a flexibility and willingness to end a flight early. A cornerstone of ADM is the pilot's evaluation of his or her own attitudes and behaviors, including the way they handle stress and unexpected events, and any attempts to modify these behaviors for the better.

ADM involves both contingency plans and a continuous decision-making cycle. Contingency plans are plans formulated in advance to be implemented in the event of certain conditions, such as weather worsening during the flight or fuel running low. The continuous decision-making cycle is the ongoing process of decision making during the flight, informed both by data prepared before the flight (including the pilot's understanding of his own abilities, the limitations of his license and of the aircraft, weather reports, a prepared flight plan, and information about conditions at the destination) and information gathered during the flight, as a result of changing conditions.

The continuous decision-making cycle calls for the pilot to constantly evaluate flight conditions and be aware of what could go wrong, such as the effects of the weather or the possibility of an engine failure. The FAA advocates the DECIDE model of continuous decision making: detect that a change has occurred, estimate the best response to the change, choose the best outcome, identify the actions necessary to respond to the change, do the chosen actions, evaluate the outcome of the actions taken. The FAA also talks about ADM in terms of the 3-P model: perceive, process, and perform. The pilot perceives the circumstances affecting the flight, processes that information, and considers the impact of those circumstances, before performing the best possible action in response.

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See Also: Aeronautics; Airplane Disasters; Airplane Pilot Licensing; Collision Avoidance Systems, Airplane.

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Aeronautics

Aeronautics is the study and development of the principles and technology of directed flight. As such, aeronautics encompasses the field of aviation as well as closely related fields, including

ballistics, rocketry and orbital satellite navigation, ballooning, and dirigible technologies. Aeronautics in the contemporary sense is largely concerned with the core physics of aerodynamics and the applied sciences of aerospace engineering, flow dynamics (subsonic and supersonic), flight surface design, and other hard scientific pursuits—as well as the “soft science” aspects of manned flight, such as business and governmental involvement in military, commercial, and private aviation policy, planning, and practices.

Flight Theory Fundamentals

If there is an “Aerodynamics 101,” it can be summed up in four words: weight, lift, drag, and thrust. These are the four key aerodynamic principles specified by Sir George Cayley in his published works of 1809 and 1810. The builder of one of the first human-carrying gliders, Cayley conceived the inter-relationships of these four forces as they applied to the design and function of all flying devices. His work’s fundamental theories were based on aeronautical ideas and works from the giants of philosophy and physical science since ancient times, with prominent names like Aristotle, Archimedes, Leonardo da Vinci, Galileo, Isaac Newton, and Daniel Bernoulli all making their contributions.

Related and integral to these four forces are such design principles as the airfoil, flow separation, aspect ratio, angle of attack, and other aerodynamic fundamentals. Cayley experimented broadly to determine the aerodynamic efficiency of various combinations of such principles, devising and testing contraptions of many types. These ranged from hot-air balloons and dirigibles to triple-decked man-powered flapping-wing planes and included his very important study of whirling-arm gliders and planes, as well as much work devoted to hot-air engines (which were rendered irrelevant by the development of gas-fueled motors).

It was in his work on the whirling-arm glider, in 1804, that Cayley achieved the most viable and useful success in early heavier-than-air flight. Many of his published interpretations of the aeronautical truths he detected as he refined this invention have stood the test of time. Other ideas have been improved upon, some discarded outright. But even today’s sophisticated, computer-aided aircraft design incorporates much of Cayley’s discoveries

about the lift, drag, thrust, and weight components of aerodynamics and their interplay.

Modern Flight

In 20th-century development of flight technology, many streams of applied science fed into aircraft design and deployment: materials science, mechanical engineering, fluid dynamics, and—especially during the last decades of the period—electronic engineering, which in its aviation applications came to be known as “avionics.”

One major theme of aeronautics in this expansive era and continuing into the 21st century has been the stability and reliability of aircraft design. Taken together, these two principles have provided the design basis for the explosive growth of aeronautics into the civilian sector, where flight has become an everyday, background feature of modern life. Inherent stability is a physics and design principle that is prudently crafted into most civil aviation aircraft. Inherent stability means that an aircraft will, by virtue of its fuselage and wing configuration, find and settle into its level, flight-maintaining attitude. This is in contrast to many military combat aircraft, for example, which are purposely designed so as to sacrifice stability in exchange for a far higher degree of maneuverability. Reliability in aeronautics has derived from materials science, engine technology and machining, better maintenance regimes, and the communications infrastructure that literally keeps pilots on course and out of harm’s way.

Another key theme has been the improved application of aeronautic guidance systems, driven in great measure by advances in avionics. Global positioning satellite networks, autopilot refinement, succeeding generations of radar development, celestial navigation, and even some aspects of artificial intelligence computing support have all contributed to the growing sophistication of aeronautic guidance technology that performs progressively better while consuming less energy and less material.

Human Factors

Underpinning all of these technological advances has been the constant, coordinated determination of commercial, military, and government authorities and administrators to organize the progress of aeronautics. This progress has come through the disciplines of better training, steadily expanding education, professional support, mandated policy

principles, regulatory development and monitoring, industrial and institutional reporting regimes, air safety guidance and investigation, intelligent use of enforcement and remediation, and increased focus on smarter planning within and outside the aviation sphere as the world's aeronautical participants grow in number even as they draw closer and become better networked.

Among the major areas of pursuit in aeronautics planning and administration are air safety, training and professional development, airspace organization, and international and regional growth planning. Each of these areas is concerned with the human factor, that is, how the individual—whether a pilot, engineer, researcher, instructor, investigator, security officer, service provider, administrator, architect, mechanic, or contractor—interacts and makes decisions within his or her immediate group, and within his or her work environment. The ongoing evolution of policies covering these interactions and performance metrics is what makes aeronautics as much a field of social organization and administration as it is one of mechanical invention and physical challenge.

Air Safety

Requirements for pilot and support personnel certification has grown into one of the main instruments in reducing air accidents and fatalities. Similarly, mandated aircraft design features and the maintenance, inspection, and overhaul schedules that commercial aviation operators must adhere to have improved the reliability and air safety records across the aeronautics world. Technological advances in air traffic control, radar and other instrument-based guidance and navigation systems, and the inclusion of more accurate airport and runway mapping in aeronautical databases continue to provide better assurance that flights take off and land in a safety-prioritized manner. Each of these advances has required the determination by policy planners that the safety of crew, passengers, and those on the ground must trump any countervailing risk stemming from purely commercial goals.

Many decisions regarding safety-enhancing practices affect the aircraft and its components, along with the standard and emergency procedures of the crew and support staff. However, there are far broader ramifications that involve issues from

airport terminal layout (key to preventing security lapses) to environmental issues (such as bird strikes and volcanic ash dangers) and ground systems redundancy (to forestall air traffic control failure due to electromagnetic surges, for example).

To enact, enable, and enforce the desired level of improvement in aeronautics safety, policy planners have recognized the need for coordinated efforts and cross-agency administration. The two most comprehensive such efforts to date have been the Commercial Aviation Safety Team (CAST) concept in the United States and the European Strategic Safety Initiative (ESSI). Both of these bodies are in turn linked to like organizations in all other parts of the aeronautics world.

CAST plans its Safer Skies Safety Enhancement series of focus areas and improvement bulletins around two main areas of endeavor: manufacturing and air carrier operations. Typical issues might include the proper installation and retrofitting of terrain avoidance warning systems, or upgraded training of flight crews on the use of advanced maneuvers to prevent and recover from hazardous conditions outside the normal flight envelope. ESSI involves more than 150 participating civil and military organizations across Europe that engage in promulgating information and policy on everything from the dramatic, such as parachute instruction, to the seemingly mundane, such as landing gear video monitoring.

Professional Development

Pilot training is the essential building block of professional development in aeronautics, but there are many other components of this field. Aerospace manufacturing, design, and quality control; avionics and telecommunications; airport planning, management, and administration; ground support services contracting; transit capacity planning, intermodal transportation and infrastructure support; air traffic control; security; accident investigation and safety initiatives; education and training; and commercial aviation legal, tax, and competitive issues all come into play.

One regulatory initiative that broadly covers these fields of study, testing, and evaluation from a federal administration standpoint in the United States is the National Aeronautics Research and Development (R&D) Policy, enacted with an accompanying executive order in 2006. This

directive empowered and directed the various cabinet-level agencies of the U.S. government to help shape, guide, evaluate, and police the development of technological innovations and human skills and activities in aeronautics. The ultimate goal of the policy is the “advancement of the nation’s aeronautics enterprise” and leadership “by fostering a vibrant and dynamic aeronautics R&D community that includes government, industry, and academia.” Individual objectives of the policy are to improve aeronautics safety, security, economic power, energy efficiency, and environmental protection, and to achieve “the highest level of scientific, technical, acquisition, and operational education and experience” among the professional aeronautics workforce.

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See Also: Aeronautical Decision Making; Airplane Navigation Systems; Airplane Pilot Training; Automated Landing Systems, Airplane; Emerging Technologies.

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Air Cargo Carriers

The business of transporting cargo by air has almost as long a history as that of commercial passenger aviation, and the early history of air cargo is intertwined with the development of postal air services. Today, air cargo services are provided by a combination of specialist companies (for example, Federal Express) and the cargo divisions of companies that also provide passenger service (for example, Korean Air), transporting over \$6.4 trillion worth of goods annually, accounting by value for about 35 percent of all world trade.

History

The air cargo industry got its start in the period just after World War I, when the availability of surplus military planes (which proved largely unsuitable for passenger service) and trained pilots facilitated the development of air mail delivery services. Subsidies from national governments for mail transport were an important source of income for early freight carriers, and it was also not unusual for the same airlines to transport passengers on day flights and mail and freight on night flights.

In Europe, colonial powers such as Great Britain, France, and the Netherlands embraced air freight as a way to maintain connections with their colonies. In 1923, a study in Great Britain concluded that the best way to meet this goal was to offer subsidies to the many small private companies then offering cargo and mail service between London and other parts of the British Empire. Imperial Airways Ltd. was formed as a result of this merger, and in 1939, it was nationalized and merged with British Airways Ltd., forming the British Overseas Airways Corporation, which later became British Airways. This pattern of many small private air cargo carriers merging into a single national airline was typical in other European countries as well, and many of these airlines remained national entities into the 1980s.

In the United States, the first air cargo flight took place in 1910, and the first dedicated postal service was established in 1918, with intercontinental postal air service beginning in 1924. The Air Commerce Act of 1926 established regulations and standards for air traffic control and pilot training, and classified the role of different airports in a national air transport system. The use of air cargo in the United States grew rapidly, and the American air



Dell computers being loaded onto a China Southern cargo plane in Xiamen, People's Republic of China, in 2009. In 2010 China Southern was the third-largest domestic air cargo carrier in the world, shipping 833,000 tons of freight throughout China.

cargo trade was the largest in the world by the start of World War II. In 1940, United Airlines began operating the first all-cargo service in the United States, and by 1945 several other airlines were also offering commercial air freight services.

In 1929, United Parcel Service (UPS) expanded its package delivery service to include goods transported on private airlines but abandoned the service within a year, due in part to lack of demand caused by the onset of the Great Depression. UPS resumed air deliveries in 1953 but did not acquire its own cargo fleet until the 1980s. DHL, founded by Brian Dalsey, Larry Hillblom, and Robert Lynn, began operation in 1969 on a single route only, offering air courier services from San Francisco, California, to Honolulu, Hawaii; it has since expanded to offer global service and was acquired by Deutsche Post in 2002. In 1971, Federal Express (FedEx) was founded by Fred Smith in Memphis, Tennessee. FedEx began operation in 1973 as an all-cargo airline, offering overnight delivery throughout the United States,

and it is now the world's largest air cargo carrier both domestically and internationally.

The Air Cargo Industry Today

The air cargo industry has enjoyed mostly steady growth since the 1960s, but the pace of growth slowed in the 1980s, and the industry has experienced periods of decline as well. The industry is vulnerable to several outside forces, including general economic conditions in the world, natural disasters, and the price of fuel (in 2010, fuel comprised over one-quarter of operating costs for airlines, according to the International Air Traffic Association). As measured in revenue ton kilograms, global air cargo traffic increased an average of 6.9 percent per year in the 1980s, 6.1 percent per year in the 1990s, and 3.7 percent per year in the 2000s. In 2008 air cargo traffic fell 3.2 percent, and in 2009 it fell another 9.6 percent, marking the first time a decline had been observed in two consecutive years.

In 2011, global air cargo declined about 1 percent, and through the first eight months of 2012, it fell 2 percent. However, even though 2011 was a year of decline overall for the air cargo business, some markets showed growth, including Latin America–Europe (3.8 percent), Europe–North America (3.4 percent), domestic China (2.8 percent), and Middle East–Europe (2.3 percent). Markets with the greatest decline in 2011 were Europe–Asia (minus 7 percent), Asia–North America (minus 5 percent), and intra-Asia (minus 0.9 percent).

Most air cargo (90 to 93 percent) is transported by scheduled air services, with the use of charter services rising during periods of strong growth. Most air cargo is carried by freighter airplanes designed specifically for goods transport rather than passengers; the percentage of air cargo carried by freighters has hovered around 60 percent since 2001. Large freighters, which are more efficient than smaller planes, play an increasing role in the business, carrying 31 percent of air cargo today, as opposed to 22 percent in 2002, and this percentage is projected to increase to 36 percent by 2031.

The leading air cargo companies today include both air cargo specialists and companies that provide both passenger and air cargo service; overall, cargo revenue comprises about 15 percent of total airline revenue. As of 2010, the largest air cargo

carrier in the world was FedEx, carrying 4.985 million freight tons of cargo domestically and 1.965 million internationally, for a total of 6.949 million. UPS Airlines was the second largest, carrying 2.929 million freight tons domestically and 1.580 million internationally, and Korean Air was the third largest, with 1.661 million freight tons internationally and 144,000 domestically. Emirates Airlines was fourth with a total of 1.777 million freight tons, followed by Cathay Pacific Airways (1.579 million). Looking at domestic transport only, after FedEx and UPS, the next three largest carriers were China Southern Airlines (833,000 freight tons), Air China (625,000 freight tons), and China Eastern Airlines (527,000 freight tons). Looking at international transport only, after FedEx, the largest carrier is Emirates Airline (1.777 million freight tons), followed by Korean Air (1.661 million freight tons), UPS Airlines (1.580 million), and Cathay Pacific Airways (1.579 million).

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See Also: Airport Administration; Economic Development; Freight Rates/Tariffs; Freight Transport Models; Globalization.

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Air Passenger Carriers

The humble beginnings of the air transportation system can be traced to a number of pioneers, pilots, engineers, business leaders, and investors who believed in the future of aviation. They strived to promote the advancement of an organized system to transport people, mail, and freight that would change the future of global transportation. Aviation, from the beginning of powered and controllable flight, offered advantages over existing modes such as shipping and railway. Since the first flight of the Wright Brothers' "Wright Flyer" on December 17, 1903, at the dunes of Kitty Hawk, North Carolina, the public has had an insatiable fascination with flight. The social awareness of the benefits of aircraft as a public utility has been apparent through rapid increases in technology over the last century. Aircraft manufacturers have transitioned from an aircraft that flew only 120 feet in 1903 to the long-range, high-performance jetliners that have become a mainstay of modern society.

Passenger travel by air became a reality for many as early as 1914, with the first scheduled air route between St. Petersburg and Tampa, Florida. Over the next decade, aircraft were developed that could fly higher and faster than their predecessors with a given level of safety, confidence, and regulation, primarily in the carriage of airmail. Even though infrastructure was not fully developed to include a complex system of airways and air traffic control in the pioneering years of air transportation, the need was apparent.

Looming world wars and global conflict during the early and middle 20th century proved the utility of aviation for wartime applications. The need for aircraft to fly greater distances for bombing runs and troop transport during World War I and World War II proved to many that aviation could play a key role in civilian infrastructure. The rapid advancements of technology during war transferred directly into the civilian sector during peacetime, allowing society to benefit from advancements in global transportation. World War II brought about systems such as turbocharged/supercharged engines and pressurization systems, which allowed aircraft to perform at high altitude. This advantage was necessary for newly established air carriers to fly above the weather and ensure passenger comfort.

At the end of World War II in 1945, the early years of the “jet age” had begun, but not without consequence. With the inception of jet aircraft making the world a smaller place and carrying large numbers of passengers, newly developed and highly untested systems had to become a component of industry. For example, the de Havilland Comet was among the earliest jet airliners to enter service; however, the lack of experience in jet aircraft design and construction would prove to be grave. The aircraft was prone to structural failures from a design flaw in the passenger cabin windows. This flaw caused the aircraft to depressurize instantly, causing a high number of fatalities. Another area of concern that had to mature was the air traffic control system. In 1956 a Trans World Airlines Super Constellation and a Douglas DC-7 collided over the Grand Canyon, killing all 117 passengers and crew onboard both aircraft. This particular incident was highly publicized and revealed a need for changes in existing infrastructure that would support more aircraft operating in finite airspace.

As infrastructure started to increase and the public appetite for travel grew, the need for air carriers to have a standardized structure became apparent. Airlines were classified by the type of aircraft they operated, distance traveled, and commodity carried. Airlines were grouped by non-scheduled charter operations, full-service legacy carriers, and regional commuter airline operations. The present air transportation system is a component of many mergers and acquisitions, which are a consistent component of the airline organizations.

Nonscheduled Charter Airlines

During the formative years of transportation by air, the public had limited trust in the reliability and safety of aircraft. Early incidents had plagued the industry with uncertainty that an individual would make it to his or her respective destination safely. This brought about air carriers who operated on an as-needed basis to transport passengers between destinations without the use of a scheduled time slot. This type of air carrier is in operation today and can be regulated under either Part 135 or Part 121 of the Code of Federal Regulations, Federal Aviation Regulations. The regulatory guideline under which each carrier operates is determined by how many passengers and what type of aircraft

each organization utilizes for service. Part 135 is the regulatory policy that provides guidance for small piston, turboprop, and turbojet aircraft carrying less than 30 people, while Part 121 regulates typically large transport category aircraft operating on a nonscheduled basis.

Nonscheduled airlines provide a utility to many passengers who choose to travel on demand or at a nonspecific time. For instance, many sports teams and large interest groups who want to travel together will elect to fly on a nonscheduled charter airline to prevent exposure to the traveling public and to spread the cost over the number of people flying. Nonscheduled air carriers may operate into smaller rural areas where other air carriers may not operate, so consumers have the overall ability to go where they want as long as performance criteria for the aircraft is met. Nonscheduled air carriers are generally smaller than their legacy or regional counterparts; therefore, they make up only a minute percentage of the airline market and are rarely considered when discussing factors that affect industry, such as financial stability and the presence of mergers and acquisitions.

Full-Service Legacy Carriers

A legacy carrier is defined as a type of airline operation that typically offers a higher level of service than smaller regional or commuter-type air carriers. They offer travel over greater distances in large transport category aircraft and include services unique to large operations, such as meals, technology, and full-service amenities. Original legacy carriers include a number of airlines that started service in the 1930s or 1940s. During this era of air carrier development, regulation was imposed and enforced by the Civil Aeronautics Board (CAB), a regulatory agency that became the predecessor of the modern Federal Aviation Administration (FAA). At the infancy of regulatory policy, lawmakers and legislators were very selective in which airlines were approved for operation. Initial startup airlines had to go through an extensive process, which included bidding routes. This process was highly political and limited new entrants to the market. Of all of the startup airlines conceived in this time frame, the “big four” gained an unsurpassed level of popularity, which would impede economic growth but mature the development of a standardized airline market. The big four were

United Airlines, American Airlines, Delta Airlines, and US Airways, all of which are still in operation today. Through this process, maturation of policy, safety, operational objectives, and passenger comfort would provide the necessary framework for the airline infrastructure in existence today.

As time progressed and air carriers became larger, so did the costs associated with travel by air. Fuel costs began to rise and the need for a different economic structure became apparent. During this time, airline ticket prices were regulated by the federal government and started to exceed the economic reach of most passengers. In 1978, the Airline Deregulation Act came into effect, which allowed new entrants easier access to the existing market. With the era of CAB regulation coming to an end and new competition exploding into the business of air transportation, policy and regulatory oversight were immature, as was the understanding of long-term economic effects. Ticket costs were driven to an all-time low, allowing more passengers the ability to travel by air, but this change in cost structure did not come without penalty to both passengers and legacy carriers.

The first of the new entrants in the market was PeoplExpress based in Newark, New Jersey. These airlines offered routes over varied distances at a cost far lower than that of any existing legacy carrier that provided service over the same route. They offered a level of service that was not as comfortable as the larger air carriers but had lower ticket prices. For instance, they charged everyone on the aircraft the same fare, with slight reductions for off-peak operating times. They also charged a fee for checked baggage at a rate of \$3 per bag, which offset some of the reductions in passenger costs. This new idea allowed substantial growth but quickly proved to be problematic to the expected longevity of the startup airline. New air carriers were forced to cease operation because the costs associated with aircraft operation exceeded the revenue gained from carrying more passengers at substantially lower costs than their competitors. For instance, PeoplExpress was in operation only from 1981 to 1987 due to this inability to survive in an evolving market.

To combat the rising cost of jet fuel and other commodities relevant to the operation of large aircraft, a number of methods were used to raise the cost of travel to consumers who purchased tickets in different time frames. For instance, a consumer



A PeoplExpress Boeing 747 in front of a Northwest Orient jet at London Gatwick Airport in June 1983. The early budget carrier PeoplExpress operated only from 1981 to 1987.

who purchased a ticket one day before the flight could pay a substantially higher fare for the same trip than someone who purchased a ticket six months prior.

A documentary by MSNBC, “A Week in the Life of American Airlines,” reported to audiences some of the ways large carriers save money on longer trips. For example, American Airlines removed galleys from aircraft on domestic flights and even olives from salads served on flights. They also used work tools as long as possible before discarding, made parts themselves, and carried only as much fuel as needed to meet the mandated fuel reserves required upon reaching their destination.

These techniques derived through data gathering and evaluation proved to save the airline hundreds of thousands to millions of dollars per year. Unique methods and techniques have been utilized by other air carriers to maximize profits where losses have accrued from the process of deregulation combined with economic recession and are necessary to survive in a somewhat ailing market.

Due to this rapid change in infrastructure and the failure of many startup airlines after deregulation, mergers and acquisitions began to take effect. A merger is defined as the combining of two or more companies. Many of the legacy carriers operating after deregulation began to purchase and acquire the aircraft, routes, and employees of failed airlines. This process is still present in the airline market today. For instance, in 2013, US Airways

merged with American Airlines in order to prevent liquidation due to bankruptcy. This has been a common process for many airlines and allows them the opportunity to restructure under the auspices of a Chapter 11 bankruptcy. Until 2011, American Airlines was the only legacy carrier currently in operation that had not claimed any form of bankruptcy since its inception; however, on November 29, 2011, it was forced to file Chapter 11 bankruptcy and pursue avenues that would carry it through the economic recession.

Low-Cost Carriers

The idea of the low-cost carrier came out of airline deregulation. Air carriers were operating with very minimal profit margins, if any; however, some modern airlines have proven that with the proper business model, longevity may be achieved. Southwest and JetBlue airlines are two examples of low-cost carriers that have had success in the air transportation market. They have both grown substantially since their beginnings; however, they are still not considered to be legacy carriers.

One primary difference that low-cost carriers incorporated into their business models is a reduction in passenger amenities. For instance, Southwest Airlines does not provide first class, business class, or any other passenger separation service that would allow for greatly varied cost variance among consumers on the same flight. This process seems to work very well during time of recessionary economic cycles, because passengers are willing to deal with the opportunity costs of flying at a less expensive rate.

Both Southwest and JetBlue airlines operate with similar profiles; however, Southwest has been established for many years—so long, in fact, that industry analysts and economists have classified a phenomena known as the “Southwest effect.” This refers to Southwest Airlines coming into a market and causing an overall increase in airline travel originating from a community after service to and from that community is established. The airline that improves service or improves cost becomes prolific in establishing a consumer base from that particular domicile for a given time frame. This is an after effect but a component of the need for that sector of society that uses air travel as a mode of transportation. Studies indicate that the majority of low-cost carriers appeal to consumers who travel less

for business and more for pleasure one may assume that business travelers prefer amenities commensurate with the time they spend in an airline seat and care less about the overall cost of the trip.

Commuter and Regional Airlines

Commuter and regional airlines are also a product of the Airline Deregulation Act of 1978. The term refers to air carriers that operate over much shorter distances than their legacy or low-cost counterparts. Passengers can expect minimal passenger comfort, smaller aircraft, and a general lack of amenities, which many express little concern with, given the lower cost associated with travel over a short distance and the advantages over travel by rail or automobile. Commuter airline success follows different models with the only difference between regional carriers being the distance passengers are carried and annual revenue in limited instances. With a general lack of differentiation defined by the Department of Transportation (DOT) between these two carriers, one may assume that operational dynamics are very similar.

Starting in the 1990s, many air carriers began viewing smaller aircraft as a tool to improve efficiency. For instance, a trip from Orlando, Florida, to Atlanta, Georgia (351 nautical miles), with an average of 75 passengers, would be inefficient for a large aircraft capable of carrying 200 passengers. A smaller aircraft carrying fewer passengers could improve the profit along the same route because the majority of seats would be utilized and the overall time difference would be negligible. This is only an example, but such changes were common before the expansion of commuter and regional carriers, causing larger airlines to accrue extreme losses in revenue. The model that commuter and regional air carriers are able to currently operate under is referred to as the “hub-and-spoke” model. This refers to the operation of large aircraft carrying large numbers of people over greater distances to utilize hubs, or centralized facilities, for a large number of incoming flights. The other component of the hub-and-spoke model are the spokes, which refers to smaller airports that are short to moderate distances away from the hub that may be easily serviced by smaller aircraft carrying fewer passengers. This model has proven efficient with legacy and regional carriers and was actually developed by FedEx, a freight organization.

The idea of common airlines operated under the same name, referred to as code sharing, has become common practice between legacy and commuter/regional air carriers, but it has proven to be controversial and to carry a level of liability. In February 2009, a Bombardier Q-400 operated by Colgan Airlines under the name of Continental Connection defined by a code share agreement with Continental Airlines crashed on final approach into Buffalo, New York, killing everyone aboard. After this particular incident, the public lashed out at air carriers. Representatives stated that because the aircraft was operated under the name Continental Airlines, it was assumed that it had the same standards regarding safety, flight duty times, etc., as the larger carrier. This incident led to improvements in regulatory policies governing code share agreements between commuter/regional carriers and legacy carriers.

Conclusion

An important consideration to take into account is how the airline industry has evolved over time. Many air carriers have come and gone; however, the system maintains its integrity through the equilibrium of economic forces and the demand of passengers. These variables help regulate air carriers with regard to route structures, operational considerations, size of aircraft, etc. Regulatory policy and guidelines established by the FAA are evaluated in order to fit the needs of future systems. For instance, the FAA is working toward NextGen technologies, which will significantly increase the efficiency of the airspace system. Off-route airways that utilize Global Positioning System (GPS) technology will allow aircraft to operate more directly from their point of origin to their intended destination. From an economic, political, and social viewpoint, the inception of NextGen technologies will decrease the amount of time aloft and work to increase revenues generated in the entire air transportation industry, thereby allowing it to conform to a level of stability defined by its future operating potential.

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See Also: Air Cargo Carriers; Air Travel; Aircraft, Regional Jet; Airline Deregulation Act of 1978; Airline Industry; Economics of Air Travel; Federal Aviation

Administration; Federal Aviation Administration Reauthorization Act of 2009; International Air Passenger Transport.

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Air Pollution, Automobiles

Automobile pollution has threatened urban air quality and climate for decades. Most pollutants are by-products of tailpipe emissions that create respiratory and/or developmental ailments in children and other at-risk populations; carbon dioxide (a by-product of fuel combustion) and other greenhouse gases (GHGs) contribute to global warming. Historically, cities with large vehicle populations have struggled to maintain healthy air environments. Progressively tighter controls on emissions rates and improved vehicle efficiency have significantly reduced such impacts, but rising motorization and the associated vehicle pollution remain serious concerns around the world. In the United States, all vehicles (cars, trucks, buses, and off-road vehicles) produce over half of the nation's smog-forming

volatile organic compounds (VOCs) and nitrogen oxides (NO_x), and roughly three-quarters of its carbon monoxide (CO) emissions. The transportation sector also contributes nearly 30 percent of the nation's GHGs (mostly in the form of carbon dioxide [CO_2]).

Most modern automobiles are propelled by internal combustion engines that consume petroleum-based fuels. Nearly all North American passenger vehicles burn gasoline, but diesel is a popular fuel in Europe and in the trucking industry. Diesel vehicles have made up less than 1 percent of new U.S. light-duty vehicle (LDV) sales (which includes passenger cars, trucks, sport utility vehicles, and vans) since the early 1980s. Both gasoline and diesel vehicles emit by-products following the combustion process that powers the vehicle. These by-products are released from a vehicle's tailpipe and dissipate in the surrounding atmosphere.

Gasoline also emits harmful vapors as it evaporates in vehicle fuel tanks and fuel lines and during refueling. Diesel is much less volatile than gasoline and does not produce a significant amount of evaporative emissions. Modern emissions control systems are able to reduce a large part of all tailpipe and evaporative emissions and are usually required on new vehicles to pass manufacturer emissions standards. (U.S. regulations do not require specific emissions control equipment, so manufacturers are free to use any combination of controls to meet standards.)

Effects

Vehicle emissions can be directly harmful as inhaled, and some also combine with secondary pollutants to produce ground-level ozone (smog) or acid rain. Direct inhalation of CO reduces the blood's ability to carry oxygen to vital organs and may cause significant damage to young children and those with preexisting heart conditions. Particulate matter (PM) also causes direct harm to humans at high concentrations and exposure levels. PM primarily affects the respiratory system, causing asthma, bronchitis, chronic obstructive pulmonary disease, pneumonia, and upper respiratory tract infections. Ozone, NO_x , and VOCs produce similarly damaging effects on human respiratory systems at various concentrations and exposures. Air pollution can also damage agricultural crops and degrade building materials and facades.

Transportation-related pollutants affect drivers, cyclists, pedestrians, and other road users, as well as those living near major roadways and freight railways. Roughly 11 percent of U.S. households live within 100 meters of a four-lane highway and so are exposed to pollution's health effects. Populations living near these areas may be economically disadvantaged or minority groups, who are often disproportionately exposed to areas of poorest air quality.

Emissions Regulations

Air quality became a major concern around the mid-20th century, as more automobiles packed the roadways and cities grew while accommodating the new mode. In the United States, the 1970 Clean Air Act set standards for automobile emissions rates and developing acceptable urban toxin levels for key health-impacting pollutants. These efforts are considered mostly successful to date: nearly all of the United States now enjoys the original air quality targets for CO, NO_x , and sulfur dioxide (SO_2).

The Environmental Protection Agency (EPA) maintains that modern light-duty vehicles and heavy trucks are up to 95 percent cleaner than models manufactured before emissions regulations took effect, and over 26,000 premature deaths, 19,000 hospitalizations, and 3.2 million lost work-days have been avoided as a result of actions taken to meet Clean Air Act requirements. Between 1990 and 2008, total U.S. VOC, CO, and SO_2 emissions were reduced 31, 46, and 51 percent, respectively. Thanks to fuel regulations, ambient air concentrations of lead, which at high concentrations can cause mental disorders in children, have also fallen dramatically: 92 percent since 1980.

Most developed countries set vehicle emissions standards that manufacturers must meet or pay penalty taxes. Some U.S. states also require periodic emissions testing to ensure vehicles meet current standards. The EPA standards allow vehicles to emit up to a maximum amount of emissions per mile, based on vehicle type, and at different levels of vehicle mileage. The EPA specifies maximum emissions limits for NO_x , PM, CO, formaldehyde (HCHO), and nonmethane organic gases (NMOG), at or below 50,000 miles (of total driving distance for the vehicle), and again at or below 120,000 miles. Standards are separated into "bins" so that certain vehicle types (like heavy sport utility vehicles

[SUVs], for instance) reside within a specific range of realistic emissions levels.

Air quality improvements have been achieved through progressive emissions regulations on new vehicles, which prompted manufacturers to improve engine design and introduce new emissions control technologies such as secondary air injection, exhaust gas recirculation systems, and catalytic converters. Catalytic converters were introduced in the mid-1970s to reduce hydrocarbon and carbon monoxide emissions, and they indirectly spurred a transition to unleaded gasoline. Up until this time, gasoline contained portions of a lead-based compound (tetraethyllead) to reduce valve wear and uncontrolled combustion (engine “knocking” or “pinging”) and improve compression ratios (for increased efficiency), but the lead component effectively inactivated the catalytic converter. Tetraethyllead’s benefits were reproduced by other, less harmful petrochemical additives, and the compound has been completely phased out of gasoline mixtures in most countries. Catalytic converters therefore led to dramatic reductions in ambient lead concentrations alongside reductions in hydrocarbons (HCs) and CO. Advances in onboard computer technologies and oxygen sensors in the early 1980s helped further reduce NO_x emissions by optimizing catalytic converter efficiency, alongside exhaust gas recirculation systems that redirect inert exhaust gas back to the cylinders.

Exhaust emissions include those emitted from the vehicle’s tailpipe during idling and driving as well as from engine starts. Emissions control equipment operates best once the engine has warmed up, leading to greater emissions during engine starting cycles. These emissions, distinct from typical running emissions with a warm engine, are referred to as “cold start emissions.” Though most CO and NO_x emissions are produced from running exhaust emissions, around 20 percent may be attributed to the cold start process. This share depends not only on the ambient air temperature but also on the amount of running emissions, which are variable among vehicles, and especially under different operating conditions—mainly running speed and engine load from hill climbing or descent. Exhaust emission (and fuel use) rates vary significantly by speed and acceleration profiles.

The EPA provides the MOVES (Motor Vehicle Emissions Simulator) tool to help model emission

rates for vehicle types under various use and environmental settings. PM_{2.5} emissions vary with speed and air temperature and can be estimated with MOVES.

Volatile Organic Compounds

VOCs are released through evaporative processes, even in some vehicles with evaporative emissions controls. Evaporative emissions are especially likely on hot days under a few different parts of a vehicle’s use cycle. For example, “running loss” emissions occur while the engine is hot, and “hot soak” emissions occur while the engine is still hot after a trip. VOCs may also be released during refueling, when the fuel tank is exposed to air, or even while the vehicle is parked and the engine is cool on high-temperature days. VOCs are mostly emitted during cold start and running, but a significant portion also includes evaporative losses during and after vehicle use, as well as while parked. The MOVES tool can estimate VOC venting as it varies across times of day and ambient temperatures and as typical gasoline passenger cars end their trips and are parked.

Alternative Automotive Fuels

Though gasoline and diesel fuels power the great majority of vehicles on the road, other fuels and propulsion systems are growing in popularity. Natural gas, in either a highly compressed (CNG) or liquefied (LNG) form is used in some commercial truck and bus fleets in the United States, thanks to its plentiful availability and competitive price. Natural gas is an attractive alternative to gasoline and diesel, due to its often cheaper cost and fewer pollutants produced at the tailpipe. Relative to gasoline vehicles, natural gas vehicles (NGVs) may reduce life cycle GHGs by around 6 to 11 percent. CNG passenger vehicles may reduce VOC emissions by 72 percent and NO_x emissions by 12 to 19 percent, relative to comparable gasoline vehicles. Despite these benefits, few personal passenger vehicles burn natural gas fuels, and the number of natural gas fueling stations (either CNG or LNG) is much more limited than those offering gasoline and diesel fuels.

In addition to pollutants that negatively impact health, focus is also placed on reducing GHG emissions that drive climate change. Automobiles are major contributors to carbon dioxide emissions, a

primary GHG; they also produce some methane, another GHG. Carbon dioxide emissions are primarily a function of vehicle miles traveled and vehicle efficiency. Efficiency depends on fuel economy (determined by engine efficiency and weight) as well as driving behavior. Rapid acceleration and braking lead to increased fuel use and therefore to higher CO₂ emissions. Even with smooth driving, vehicles are most efficient at cruising speeds, between 30 and 60 miles per hour. In congested conditions, vehicles have the highest emission rates, but efficiency decreases at higher speeds as vehicles exert increasingly great amounts of energy to overcome large drag forces. Other automobile pollutants also follow this general trend, which adds motivation to reduce roadway congestion.

Electric and hybrid electric vehicles (HEVs) offer further ways to reduce tailpipe emissions, to as much as zero in the case of a fully battery electric vehicle (BEV) or hydrogen fuel cell vehicles. While electric vehicles improve local air quality, their use may simply shift pollution to upstream point sources (power plants), and generating electricity from coal plants to run BEVs may produce more total emissions than would HEVs that uses gasoline to power an electric motor. As new HEV and BEV models emerge around the world, consumers have more opportunities to pollute less per mile driven.

Even with the introduction of promising new automobile technologies (and greater use of renewable feedstocks for electric vehicle power), pollution remains a concern. Fleet turnovers are slow and gradual, and many new car owners are anticipated in China's and India's big cities as well as elsewhere. North America, Europe, and many other developed regions have managed to significantly reduce automobile emissions but still face challenges as urban growth continues. Achieving and maintaining clean air and more efficient vehicles around the world will dramatically improve health, reduce degradation of the built environment, and avoid negative impacts to agriculture and the natural environment.

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See Also: Air Pollution/Air Quality; Automobile Emissions Controls; Carbon Dioxide Emissions;

Carbon Monoxide Emissions; Clean Air Act and Amendments; Diesel Fuel Vehicles; Electric Vehicles; Emissions Modeling; Environmental Protection Agency; Gasoline, Reformulated; Gasoline Engines; Green Fuels; Greenhouse Gases; Hydrogen Fuel Cells; Lead Pollution; Low-Emission Vehicles; Nitrogen Oxides; Particulate Matter; Smog; Sulfur Dioxide; Vehicle Emissions Standards; Vehicle Fleet Emissions; Volatile Organic Compounds; Zero-Emissions Vehicles.

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Air Pollution/Air Quality

The transport sector is one of the main contributors to local and regional air pollution and has direct impacts on human and environmental health that are particularly pronounced in urban areas. This article discusses the most common air pollutants emitted by surface transportation and the main factors that influence their concentration in ambient air. Major trends in these emissions are highlighted for the United States and Europe, their human health impacts are described, and U.S. and European Union (EU) air quality regulations are briefly introduced.

Transportation Sources

In addition to carbon dioxide (CO₂), a major greenhouse gas, the combustion of fossil fuels in surface transportation produces the following:

- Carbon monoxide (CO)
- Nitrous oxides (NO_x), consisting of nitrogen dioxide (NO₂) and nitrogen monoxide (NO), which under solar irradiation and with ambient oxygen form ozone (O₃) as a secondary pollutant
- Sulfur dioxide (SO₂), a major contributor to acid rain
- Volatile organic compounds (VOCs), another contributor to O₃ formation
- Particulate matter (PM), which is composed of different solid and liquid substances collectively defined by their very small particle diameter of below either 10 (PM₁₀) or 2.5 μm (PM_{2.5}; 1 μm or micrometer is 1 millionth of a meter)

PM is also created through abrasion of brakes, clutches, tires, and road surface materials, and it is often resuspended into the air column through the turbulence from passing vehicles once it has settled on the ground. Because part of the total PM found in the air comes from sources other than transport, these resuspended particles may originate from industry, home heating emissions, dust from construction sites, or biological matter such as fungal spores or pollen. VOC emissions further arise through evaporative losses from carburetors, fuel tanks, and at filling stations. By 2012, the sale of leaded gasoline had been phased out in most if not

all countries globally, but lead from other sources can still be detected as an air pollutant.

The nature and quality of the fuel burned has an important impact on associated air pollution effects. Diesel fuel—used in virtually all heavy goods vehicles, nonelectric train engines, many buses, light trucks, and passenger cars—creates significantly higher PM emissions than gasoline. Biodiesel (from vegetable or animal matter) generally results in lower CO, PM, and hydrocarbon but higher NO_x emissions than conventional diesel. Gasoline has a significantly higher content of VOCs than diesel. The mixture of oil and gasoline required by the two-stroke engines of small two- or three-wheelers (for example, mopeds, scooters, motor rickshaws) results in much higher emissions of smoke, CO, VOCs, and PM per unit of fuel burned than pure gasoline.

The fuel used in shipping can contain up to 3,500 times more sulfur than is permitted for fuels used in land-based transportation: 10 parts per million or 0.001 percent allowed in liquid fuels for land transport in the European Union and California, 15ppm in the rest of the United States versus 3.5 percent permitted for international shipping by the International Maritime Organization. Compressed natural gas (increasingly used in urban buses, for example) burns cleaner than other fossil fuels, producing lower CO₂, CO, and hydrocarbon but higher NO_x emissions. Hydrogen has no carbon content and thus hydrogen engines do not emit carbon compounds, though depending on the energy source, they may be created when hydrogen fuel is generated.

Other processes associated with transportation also play a role in air pollution. Refining liquid fuels from crude oil results in significant local emissions of CO, NO_x, hydrocarbons, particulate matter, and sulfur compounds, although air quality regulations in the United States and the EU require refinery gas to be of a certain quality before its release. Even the spray painting of vehicle body parts in local workshops can release notable amounts of VOCs into their neighborhoods.

Weather and topography further influence local and regional levels of air pollution from transport activities. In high-pressure weather systems, temperatures in the air column can increase with distance from the ground. In combination with low wind speeds, such inversions can trap pollutants

near the earth's surface, where they accumulate. So-called smog is a consequence of such conditions and can lead to visible "pollution ceilings" above urban areas. The problem can be exacerbated by local topography, if a basin location or nearby mountain ranges prevent the dispersion of air pollutants. Smog was originally associated with coal and wood smoke from industry, power generation, and domestic heating rather than with transport emissions (smog = smoke + fog). The more recent version, photochemical smog, contains compounds created through chemical reactions between NO_x , hydrocarbon compounds (part of the group of VOCs mentioned above), and ambient oxygen. Elevated ground ozone levels are one result of these reactions, which are facilitated by solar irradiation. Transport emissions are the main contributors to photochemical smog, which is primarily observed over large urban areas.

High wind speeds can help disperse air pollutants more quickly away from their source, reducing their local concentrations. However, depending on prevailing wind directions, air quality can in turn be affected in areas that are quite remote from the original source of the pollutants or their precursors. A prominent example can be found in the U.S. Yosemite National Park, which in summer frequently experiences strongly elevated ozone levels as a consequence of emissions created in the San Francisco Bay area, about 200 kilometers away. This phenomenon affects both visitors and plant life. Comparable and longer-range transport has been shown for NO_x and particulate matter, with associated consequences for the health of people and ecosystems.

Trends

In the United States and Europe in 2010, of five major air pollutants (CO , NO_x , SO_2 , $\text{PM}_{2.5}$, SO_2 , and VOCs), transport produces more NO_x emissions than all other sectors (commercial, institutional, and household fuel combustion, and the energy sector and industrial processes) and ranks second or third on other pollutants, excluding SO_2 , where the main share of emissions in both regions in 2010 is created by coal burning in the energy sector. The variations between these two world regions have at least three reasons. First, different transport modes contribute differently to the totals: in Europe, international and domestic shipping

plays a much larger role than in the United States, for example, and this significantly increases the transport sector's relative contribution to overall sulfur dioxide emissions (fourth column). Second, the relative contribution of nontransport sources depends on the respective fuel mixes (coal, oil, gas, nuclear, renewables), the types of industry, and the overall volume of their emissions relative to those from transport. Third, the compilation of such statistics relies on a combination of measured and modeled data from secondary sources, the quality of which may vary.

The trend in emissions of the same pollutants from transport activities in relation to 1990 as the base year also showed decreases relative to their 1990 levels, though not at the same rate. Taking into account the methodological change in measuring SO_2 emission in the United States, sulfur oxides emissions from land-based transport have reduced substantially in both Europe and North America due to fuel-quality regulations. That situation is different in other parts of the world, though, where up to 300 times higher sulfur levels are still permitted in diesel fuels for land-based transport. The widespread introduction of catalytic converters has greatly contributed to reducing CO and VOC emissions. Emissions of these three groups of substances have decreased much more rapidly than $\text{PM}_{2.5}$ and NO_x —though none have disappeared completely.

$\text{PM}_{2.5}$ arises in the transport sector from sources other than the engine and is harder to eliminate from tailpipe gases than larger particles, for example. Nitrous oxides are created in the engine from nitrogen present in the air needed for combustion and thus cannot directly be addressed through fuel quality. In addition, the use of alternative fuels sometimes results in higher NO_x emissions than from conventional diesel or gasoline.

Quantifications of air pollution are very sensitive to the chosen methodologies, which may vary between regions and over time. This should be borne in mind in their examination and comparison, though their importance and usefulness are undisputed.

The trends described above are averaged over large areas and while it is generally true that air pollution from transport there has decreased over the last decades, the nature of this development is not the same everywhere. Local and regional transport



A line of cars passes through an area of severe air pollution from heavy industry on Clark Avenue in Cleveland, Ohio, in July 1973. The Clean Air Act of 1970 and its amendments helped lead to an improvement in average air quality across the United States. Between 1990 and 2008, total U.S. volatile organic compounds, carbon monoxide, and sulfur dioxide emissions were reduced 31, 46, and 51 percent, respectively. Fuel regulations have also led to a 92 percent decrease in ambient air concentrations of lead since 1980.

emission trends may be either better or worse, depending on, for instance, the specific development of transport volumes and fleet composition.

Health Impacts

Experts now generally agree that there are no threshold effects for the classic air pollutants from the transport sector: carbon monoxide, nitrogen dioxide, particles, ozone, and sulfur dioxide. In other words, it has not been possible to show any level at which these substances do not have a negative impact on human health, though the nature and magnitude of this impact varies with the concentrations people are exposed to and with the length of that exposure. In general, the increased mortality linked to chronic exposure to air pollution is thought to be greater than the mortality risk

linked to acute exposure. Studies on the number of premature deaths caused by emissions from the transport sector in Europe and the United States generally estimate figures on the order of tens of thousands. Connections between chronic exposure and increased morbidity (for example, cardio-respiratory problems, pulmonary function) have also been found in both children and adults.

Specific health impacts from transport include the effects of carbon monoxide, nitrogen dioxide, particulate matter, sulfur dioxide, volatile organic compounds, and ozone. Carbon monoxide (CO) binds to hemoglobin with a 200-times-greater affinity than oxygen to form carboxyhemoglobin (COHb), decreasing the delivery of oxygen to the cells. Increases in COHb create cardiac stress and can exacerbate or bring on symptoms of angina

pectoris. While legal limits for ambient CO are now rarely exceeded in developed countries, prolonged exposure can still result in personal COHb levels becoming elevated.

Elevated levels of nitrogen dioxide (NO₂) are associated with impaired lung function in asthmatics and possibly also with higher sensitivity to allergens.

Particulate matter (PM) can have different physiological and toxicological effects, depending on composition and particle size. The smaller the particles, the farther they can penetrate into the human body and the worse are the health effects associated with them. PM₁₀ can cause irritation to eyes, nose, and bronchi, while smaller particles in the PM_{2.5} fraction can penetrate as deeply as the lungs's alveoli, from where they may reach the blood. Exposure to PM is associated with acute respiratory problems, prolonged respiratory illness, cardiovascular diseases, and exacerbation of existing pathologies (such as asthma). Chronic exposure to PM is likely to shorten life expectancy.

Sulfur dioxide (SO₂) in high concentrations causes irritation of the upper respiratory tract and other membranes in eyes and nose. It can worsen the symptoms of asthma and is associated with elevated numbers of hospital admissions (a common health effect marker in epidemiological studies) and even increased mortality due to pulmonary and cardiovascular diseases.

The term *volatile organic compounds* (VOCs) describes a group of substances many of which are toxic or known carcinogens, such as 1,3-butadiene, benzene, and polyaromatic hydrocarbons.

Human exposure to elevated levels of ozone (O₃), a secondary pollutant from the transport sector, results in reduced lung functions in both asthmatics and non-asthmatic individuals, though health effects seem to be more severe in those already suffering from chronic respiratory problems. While symptoms associated with short-term exposure to elevated O₃ levels (such as coughing and shortness of breath) do not normally persist, long-term exposure might cause more severe and lasting damage.

Regulations

Under the Clean Air Act (CAA, 1990) the U.S. Environmental Protection Agency must set National Ambient Air Quality Standards (NAAQS) for six common air pollutants: PM, ground-level O₃, CO,

SO_x, NO_x, and lead. The CAA had a major impact on air quality in the United States.

In the member states of the European Union, the main driver for a continuous assessment of urban air quality and its improvement in connection with road transport is the EU's Directive on Ambient Air Quality and Cleaner Air from 2008. It defines limit values for CO, PM₁₀, PM_{2.5}, SO₂, NO₂, NO_x, benzene, and lead. The translation of this directive into national legislation was mandatory for EU member states. It has resulted in an obligation for the relevant public bodies to monitor or model immissions of these substances and take action if legal limits are exceeded. Many European cities are failing to meet the current limits for PM₁₀, PM_{2.5} and NO₂.

In most cases, air quality standards represent a compromise between what is theoretically required from a public health or environmental point of view and what is deemed politically feasible or desirable. The same applies to the way air quality is assessed, that is, the density and siting of monitoring stations.

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See Also: Aircraft Engine Emissions; Airports, Environmental Issues and; Automobile Design; Carbon Monoxide Emissions; Clean Air Act and Amendments; Congestion Mitigation and Air Quality Program; Emissions Modeling; Health Issues; Lead Pollution; Low-Emission Vehicles; National Ambient Air Quality Standards; Nitrogen Oxides; Particulate Matter; Vehicle Emissions Standards; Zero-Emissions Vehicles.

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Air Taxis

Air taxi operations are on-demand charter flights, especially passenger flights but including cargo aircraft. They are principally a phenomenon of the 21st century, with most air taxi companies founded during or after the post-9/11 development of the Small Aircraft Transportation System (SATS), a joint project between the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA). One of the advantages of air taxi services is their use of general aviation airports, of which there are approximately 10,000 throughout the country, compared to the 330 airports served by commercial airlines.

When security measures were increased following the September 11, 2001, terrorist attacks, the aviation industry and its patrons suffered from significant increases in the time passengers spent in the airport prior to their flight. The SATS project studied general aviation—all forms of civil aviation other than the scheduled air services of the airlines—as a remedy to the problem. The possibility of strengthening general aviation, which is served by a significantly larger number of airports in the United States, had been discussed in the industry for decades, and the SATS name came from a 1997 NASA presentation. SATS focuses on addressing travel needs through the use of small aircraft rather than large jet airliners used as mass transit. The main concern was safety issues: weather has a greater effect on small aircraft, whose pilots may be less experienced than pilots of commercial jet airliners, and the safety record for general aviation overall is poorer than that of scheduled air service. Increasing the volume of general aviation traffic without addressing this would be problematic.

The SATS work, conducted from 2001 to 2006, fell into four broad areas: high-volume operations without control towers, improved landing systems usable in most weather conditions, higher capacity air traffic control systems usable in general aviation, and improvements in pilot abilities.

Eclipse Aviation and DayJet

The end of the SATS project coincided with the official introduction, after years of development, of the Eclipse 500 from Eclipse Aviation, the first of a new class of aircraft called the very light jet (VLJ). The VLJ is a small jet aircraft for a single pilot with 4–8

passengers, and it filled the niche SATS sought to fill. While some VLJs are used for personal use, they have provided the backbone of the air taxi industry, with faster speeds than older classes of small aircraft and significantly lower operating costs than larger jets, as well as the ability to take off and land on much shorter runways (as short as 3,000 feet).

The term *very light jet* has been somewhat deprecated because of the bankruptcy of Eclipse Aviation, and the failure of DayJet, the pioneering air taxi service that used Eclipse 500s. DayJet, based in Florida, began operations in October 2007 with a fleet of 12 Eclipse 500s and a series of orders totaling 1,400 of the manufacturer's 2,500 orders. Beyond the use of smaller jet aircraft, the key to DayJet's service and the air taxi industry as a whole was its on-demand nature. Rather than schedule flights and layovers according to complicated algorithms and then seek passengers to fill them, as the scheduled air service industry does, air taxis take a small group of passengers to their destination on demand.

Instead of expanding as planned, DayJet was quickly forced to scale back its fleet because of prevailing economic conditions, and it ceased operations on September 19, 2008, as the worldwide financial crisis crested. DayJet and Eclipse's fortunes were entangled. Eclipse's lack of funding had halted the production of the Eclipse 500 a few months before the DayJet closure, and Eclipse became the broker selling off DayJet's fleet, while itself entering into bankruptcy in November 2008. Its assets were acquired in August 2009 by Eclipse Aerospace, a company formed expressly for that purpose.

The Industry

The collapse of DayJet was prominent enough that many believed the air taxi industry had died with it, but in truth the industry was still getting started. However, two other companies, Pogo and SatsAir, have similarly gone out of business due to insufficient capital. Nevertheless, by 2013 some two dozen companies offered air taxi service in the United States, in addition to Canadian firms. Some had fleets with as few as five aircraft, and many served only specific regions (much as taxicab companies do on the ground).

The term *very light jet* is sometimes still used in the industry and by the FAA, but in dealings with the public, the term *personal jet* tends to be more common, though describing the same types of

aircraft. Cessna's Citation Mustang with six seats, along with the Embraer Phenom 100, is one of the most successful VLJs now that the Eclipse 500 is out of production, although Eclipse aircraft continue to be used as well. The Phenom 100 (used by JetSuite, founded in 2009 in Orange County, California) is the only common VLJ to come equipped with a fully enclosed lavatory as a standard feature. Other VLJs offer the option of sacrificing a passenger seat in favor of a lavatory enclosed by a curtain. Air taxi service typically revolves around hour-long flights, for which an on-board lavatory is not considered crucial.

As with any other transit service, one of the keys to a successful air taxi business is reducing the number of empty legs—flights without passengers—necessitated by needing to move the aircraft to another airport to pick up passengers. Ideally, roughly equal numbers of passengers travel from Point A to Point B as from Point B to Point A, though more complicated arrangements are equally acceptable, so long as aircraft are kept in use and the number of empty or underfilled legs is kept low. This is where much of the challenge of the business model lies. With a larger fleet, the significance of any one empty leg is lower, provided the fleet as a whole is kept active and full; however, an empty leg is a greater burden for a company offering only a few flights. Building up a base of repeat customers can also be important.

Some air taxi providers have also benefited from partnerships with commercial airlines. JetSuite, for instance, partnered with Singapore Airlines to provide service for passengers to and from major metropolitan airports. While many major airlines partner with smaller regional carriers for service to smaller airports, the advantage JetSuite offers to Singapore Airlines is service to general aviation airports that have no commercial airline service. JetSuite, in turn, benefits from introducing airline customers to its service. (JetSuite has also led the industry in social media outreach, notably a \$1 airfare promotion that brought significant attention to its Facebook and other social media pages.)

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See Also: Air Passenger Carriers; Aircraft, Regional Jet; Aircraft, Very Light Jet; Aviation, Commercial/Business.

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Air Traffic Control

No mode of public transportation has a greater emphasis on safety than the aviation industry. From manufacturing to maintenance requirements, every phase of air travel is closely scrutinized to ensure the safest environment for the air traveler. This same mind-set extends into the role of the professional air traffic controllers who must move the vast number of daily flights and the passengers aboard them. These efforts have resulted in the development of the safest mode of travel available—commercial flight. The thousands of daily flights that involve private general aviation aircraft also factor into this mix.

So how does one constantly mix the largest of jumbo jet aircraft with the smallest of privately owned aircraft and still maintain the level of safety demanded by the flying public? The Federal Aviation Administration (FAA) has structured the National Airspace System (NAS) in a manner to ensure the separation of aircraft from other aircraft that share the crowded skies. Through years of aviation accident investigations and incident reports, the FAA has also constantly developed and revised specific procedures and phraseology that must be adhered to by all air traffic controllers. These procedures and specific ways of communicating with the aircraft, and with other controllers, ensure that the controllers maintain a safe, orderly, and expeditious flow of air traffic.

Preparing for Safety

To be able to comprehend the methods of separating aircraft, it is necessary to be able to visualize airspace as a three-dimensional block when looking at the flat surface of a radar scope. Air traffic controllers are trained to form a mental picture of the constantly changing traffic situations taking place within their airspace of responsibility. They ensure that the traffic is kept apart by applying rules of separation that are broken down into miles, altitudes, airspeeds, and times. Remembering that three-dimensional picture, one must understand that all the aircraft that a particular controller is working are being separated vertically, laterally, longitudinally, or visually. To further complicate the air traffic picture, factor in the differences in aircraft performance capabilities, such as airspeed, climb rate, and wake turbulence situations caused by mixing larger aircraft with smaller ones.

Every procedure and every phrase to be spoken, and how it is to be spoken, is provided by the FAA in great detail in one publication. The *FAA*

Handbook 7110.65 is the procedural bible for air traffic control operations, procedures, and phraseology. The FAA uses this publication to mold every air traffic controller and to guide them in their daily operations for the rest of their careers. This ensures uniformity and a mutual understanding of all of the safety requirements and how they are to be maintained.

Air traffic controllers begin early with the training process. The vast majority of controllers are graduates of Air Traffic-Collegiate Training Initiative (AT-CTI) schools. These are colleges and universities selected by the FAA to provide training to undergraduate students attending these institutions. The training includes classroom lectures, laboratory simulations, and assessments of the students' performance. During their training, the controllers are exposed to as many types of emergencies as possible through the use of simulation. This helps in the development of a fine-tuned response that is mostly human reflex. The students are taught that the first operational priority of air



Air traffic controllers at work in a new 11-story control tower at Pope Field, North Carolina, in June 2013. Air traffic controllers must keep aircraft that are at the same altitude, or close to it, at a lateral distance of either 3 or 5 miles from each other, depending on their distance from the radar. If an aircraft is over 40 nautical miles from the radar, the 5-mile lateral separation is required because radar becomes less accurate the farther an object is from the antenna.

traffic control is to separate aircraft and to issue safety alerts. A safety alert is defined as an aircraft coming within close proximity of basically anything that will make it come to a sudden stop, such as an obstruction, terrain, or another aircraft.

Safety Measures in a Radar Environment

Over the years, the FAA has devised a strong and proven system of separating aircraft. Presented here is a brief overview, or explanation, of how that system actually works. The goal of any separation system is to keep the targets separated. This is not rocket science. The first requirement is to establish a minimum distance that must be maintained to separate aircraft. This is called the separation minima. It is quite a logical system. Remember, as previously stated, all aircraft are being separated vertically, laterally, longitudinally, or visually. Approach control works the traffic in the air around the airport and usually out to a distance of approximately 60 miles with varying upper-level ceilings, depending on the airspace structure allocated to them.

For aircraft at the same altitude or less than 1,000 feet apart vertically, the minima is either 3 miles or 5 miles. The exact distance required between the aircraft is determined by how far the aircraft are from the radar antenna. Radar is inherently more inaccurate the farther an object is from the antenna. To allow for this “slop” within the system, the FAA has established a range of 40 nautical miles as the changeover point. If the aircraft to be separated are within 40 miles of the antenna, the controller must maintain 3 miles between the targets. If the aircraft are 40 or more miles from the antenna, the controller must maintain 5 miles between the targets. This is called lateral separation because the range is the lateral distance between the aircraft. Remember, they are at the same altitude.

Most air travelers have landed at a large, high-volume airport with parallel runways and, looking out the window, have seen other aircraft landing at the same airport that were less than 3 miles away. So, how can this be legal after reading and understanding the rules given above for lateral separation? It is really quite simple. When parallel runways are located more than 2,500 feet apart, they are considered to be a single runway and simultaneous operations may be conducted without regard for the lateral separation requirement. This operation is perfectly safe and allows the controllers to

expedite the arriving traffic. Imagine how much of a delay there would be if 3 miles had to be maintained between each arriving aircraft at an airport with the traffic volume of Atlanta or Dallas/Ft. Worth airports.

For aircraft that are receiving vectors, or turns, within the arrival traffic pattern to position them for landing on the runways at an airport, vertical separation is also used. When controllers are using vertical separation, they are keeping the aircraft separated by 1,000 feet vertically. Controllers ensure that all arriving aircraft receive the local altimeter setting, or barometric sea-level pressure, as they arrive into the airspace. Therefore, all aircraft under one approach controller’s jurisdiction will be using the same altimeter setting, ensuring a uniform, consistent measurement of distance between each aircraft. Having all aircraft use the local altimeter setting ensures that the vertical distance between aircraft is accurate and the controller is using the aircraft’s exact altitude, since altitude is measured by pressure differential, or variation, from sea level. All aircraft below 18,000 feet operate on local altimeter settings.

All these rules and measurements work fine as long as you have a method to measure them—radar. What do controllers do when the radar is inoperative for some reason? This is a rare occurrence, but it does happen, and the safety requirement does not go away just because the aircraft cannot be seen on radar anymore. Controllers must resort to using position reports provided by the pilots and the distance reported by the instruments in the aircraft that have distance-measuring equipment, or DME. This measurement is combined with time, altitude, and the use of land-based navigation aids to provide the required increased separation between aircraft. Although safe, this process is extremely slow due to the increased radio communications involved with requesting and receiving position reports and the additional distance required between arriving aircraft when working without the advantage of radar.

Safety in Tower Operations

The most visible of air traffic facilities is the control tower. When most people think of air traffic controllers, they usually think of the controllers in the tower. This seems logical since the control tower is usually seen someplace on the airport and the radar controllers are located in some obscure building out of sight. Just as in radar facilities, the control tower must

exercise safety measures during aircraft movements as well as during interactions with other controllers, both in the tower and in other facilities. Although each facility has its own area of traffic jurisdiction, the tower and radar controllers are constantly working closely together to ensure traffic safety.

The control tower is aware of every aircraft movement that occurs on the airport surface. Even if an aircraft is to be towed from one position to another, the tower must approve the operation. From the time the aircraft is pushed back from the loading gate until it lifts off the runway during its takeoff, it is monitored and directed by the control tower.

The ground controller issues taxi instructions to the aircraft when it is ready to taxi from the terminal loading gate to the departure runway. The aircraft's progress is closely monitored by the ground controller, and the aircraft is informed of any other aircraft and other ground traffic in its immediate vicinity as it moves along. Basically, aircraft on the ground are controlled in the same manner as vehicle traffic on the streets. They are given specific taxi instructions telling them which taxiways to use to get to the end of the runway for departure. Taxiing aircraft are told when to stop and when to go at different taxiway intersections and when to give way to other aircraft as the tower establishes the aircrafts' positions in the departure sequence.

The most critical safety areas on the airport surface are the active runways. Mixing high-speed arriving and departing aircraft using the same surface requires a controller's full and undivided attention. Factoring in the numerous runway crossings, both by taxiing arriving or departing aircraft and by ground vehicles, the runway becomes an area with an extremely high potential for disaster. Literally hundreds of thousands of lives encounter this potentially dangerous environment every day across the nation.

To ensure the safety of the aircraft during runway operations, close interaction and coordination are required between the two air traffic controllers responsible for its success or failure. The ground controller is responsible for the movement of all aircraft on the airport that are not on the runway. The local controller is responsible for all airborne traffic around the airport and any aircraft that are on the runway. Therefore, if the ground controller wants to taxi an arriving or departing aircraft across the active runway, he must first obtain permission from the local controller. The local controller may

instruct the ground controller to hold the aircraft short of the active runway or she may give permission for the aircraft to taxi across the runway.

Regardless of which instruction is given to the ground controller, the instruction is repeated back to the local controller verbatim. This is a built-in safety measure that ensures there is no miscommunication or misinterpretation of the instructions by either controller during this sensitive operation with such a high potential for disaster if mistakes are made. This is one operation that advanced technology has not replaced. There are still certain times in air traffic control when nothing can replace old-fashioned eye-to-eye contact and face-to-face coordination to ensure safety of aircraft involved.

Sequencing and landing the arriving aircraft, as well as clearing departing aircraft for takeoff, is the responsibility of the local controller in the tower. This controller must also adhere to strict safety rules and guidelines when balancing arriving and departing aircraft. Factors such as the aircraft's performance capabilities and potential for wake turbulence must be constantly taken into consideration.

A great amount of skill and judgment is required to perform the duties of an air traffic controller. These attributes, combined with the safety mechanisms the FAA has developed and implemented, make the complex world of air traffic work in a seemingly simple manner.

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See Also: Air Traffic Controller Training; Air Traffic Flow Management; Air Travel; Collision Avoidance Systems, Airplane; Federal Aviation Administration; National Airspace System.

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Air Traffic Controller Training

The training of air traffic controllers is one of the most important issues that the Federal Aviation Administration (FAA) faces today. The primary job of an air traffic controller is to provide a safe, expeditious, and orderly flow of air traffic to prevent a collision between aircraft operating in the national airspace system. Typically, high-traffic workloads can lower performance and set an upper limit on traffic-handling capacity, whereas times when traffic workloads are low can result in boredom and reduced alertness.

One approach to meeting the training need is the use of simulation. By using simulators, controllers gain inherent knowledge of a particular airport, its airspace, and application of air traffic procedures for that specific location. A computer-generated simulation can create multiple air traffic control situations, allowing controllers to respond as they would in a real situation. This method of training is in alignment with pilot training.

Today, with many airlines, a newly hired pilot has already learned to fly, has accumulated the appropriate number of flight hours, and is type-certified prior to being hired. Conversely, air traffic control trainees, or “developmentals,” enter training at air traffic control facilities with basic knowledge. Much of the training at operational facilities is accomplished as developmentals handle live traffic, closely supervised by certified professional controllers. On average, between 1,000 and 2,000 hours of combined on-the-job training and work experience is needed at an en route air traffic control facility or a busy terminal radar facility before a new controller has enough skill and knowledge to attain full certification. Therefore, reducing the amount of time to train a controller without jeopardizing safety is paramount.

Simulation Fidelity

A standard definition of “simulation fidelity” is the degree to which the simulation emulates the real system. Several training sources have provided definitions for “simulation.” These definitions cover basic or part-task simulation, low-fidelity simulation, medium-fidelity simulation, and high-fidelity simulation. Basic or part-task simulation is the imitation of a behavior or task but lacks

functional and environmental fidelity. Essentially, these are systems that do not require visual displays or hands-on control functionality. Low-fidelity simulation is the basic modeling with desktop computers and monitors with some imitation of input devices. Low fidelity may include visual displays or control interaction and has the ability to practice multiple types of errors. Medium-fidelity simulation includes more equipment functionality that does not require visual systems or highly realistic controls. This level of simulation fidelity can be used for practicing procedures such as emergency response and flow controls. High-fidelity simulation is near-system fidelity that can simulate multiple weather environments and the ability to emulate real-world events and features. Some examples of high-fidelity features are generating traffic and aircraft types in high-value training situations like departure overtakes, slow-climbing aircraft, en route overtakes, inverted holding pattern stacks, crossing traffic for departures or arrivals, sequencing problems, sector saturation, scanning complexities, and others.

Simulation Benefits

Any simulation equipment must be able to stimulate the most common cognitive abilities and psycho-motor skills that have been identified in several studies dealing with air traffic control. Cognitive abilities are memory skills, numerical ability, spatial ability, and speed and accuracy in perception. Psycho-motor skills include the effective use of keyboard, trackball, mouse, coordination, and consistency of required actions. In the world of air traffic control training, there are several companies that provide different versions and levels of simulation equipment. These systems allow students to experience the look and feel of air traffic control; the stress of controlling multiple targets and making sure they are separated has tremendous benefits over the old true and tried method of lecture-only sessions. A good simulation product can have a dramatic effect on the entry-level controllers in a number of areas. First, there is safety in the simulation environment. Real-world situations can be programmed into scenarios that allow students to try to work their way out of problems that might be experienced with live traffic. Also, scenarios can emulate situations that are designed to enforce procedures that are unique to

air traffic control and not seen very often. Finally, with the ability to teach procedures, airspace, and techniques, simulation will build confidence in the students and reduce the pressure on them. As with pilots, developmentals, or trainees, can be much better prepared and confident before they actually begin working live traffic. In such a critical part of the American economic infrastructure, the need to train air traffic controllers quickly, efficiently, and safely should far outweigh the costs.

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See Also: Air Traffic Control; Airplane Pilot Training; Collision Avoidance Systems, Airplane; Federal Aviation Administration; National Airspace System .

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Air Traffic Flow Management

Air traffic flow management (sometimes abbreviated ATFM) is the regulation of air traffic with the objective of avoiding either exceeding or running below the optimal capacity of a given airport. At its most deceptively simple, ATFM is based on the premise that only one craft can land or take off at a given time. When runway capacity is not fully used, passenger delays increase and profitability suffers for a variety of reasons. Conversely, when runways are operated over capacity, the risk of collision and other dangerous events increases. Thus, it is in the best interest of safety and efficiency to regulate with great precision the location of each aircraft on each runway within any given airport.

Safely Maximizing Efficiency

Proper air traffic flow management is, at its core, all about balancing safety and efficiency. The most obvious danger in running above capacity is the risk of collision between aircraft. Simply put, the closer together the moving craft, the higher the risk of collision. The risks associated with running below capacity are less obvious, and they are not nearly as dramatic. From a business standpoint, it does not make financial sense to run fewer aircraft on the airport's runways than the facility is capable of handling. Furthermore, inefficient air traffic flow management can cause significant delays in flight schedules, which can cause systemic delays across a region if delays within a facility become severe enough.

Several factors dictate the maximum capacity of any given facility. First, and most basically, capacity is determined by the number of runways available. The layout of taxi tracks may also dramatically affect facility capacity. Taxi tracks are those runways that

are reserved for short-distance commuter planes. When properly separated from runways for other aircraft, taxis are able to cycle through the facility at a greater rate, and larger planes are able to take off without delays caused by taxis.

Proper air traffic control is the most effective moment-to-moment solution to air traffic flow management. The work of air traffic control staff is to direct traffic in and out of the facility. This is one of the key areas where proper staffing can dramatically affect the capability and safety of an airport. Just as critical as staff is proper air traffic control equipment. Faulty or outdated equipment may also have a detrimental effect on the output of the airport. Finally, weather conditions dictate the capacity of the facility, but proper air traffic control can mitigate even this most chaotic of factors.

The capabilities of air traffic control workers are greatly influenced by capacity. The factors that dictate facility capacity and may be controlled via proper management in the midterm are of special interest to those interested in facility productivity. These factors are understaffing and the continued use of outdated or faulty equipment. Understaffing is the condition of not having enough qualified employees for safe and efficient airport operation. Understaffing is a problem not only at small or low-budget airports; understaffing has been a dangerously serious issue at major airports, including Chicago's O'Hare International Airport. In the early 1990s, O'Hare was the site of one of the most dangerous facility environments in modern aeronautic history. Despite the presence of a unionized workforce and associated staffing regulations, air traffic control staff were forced to work six-day weeks. This dangerous practice has been scientifically shown to contribute to burnout and greatly diminished productivity of the existing workforce. In 1988, 33 incidents occurred in which planes came dangerously close to colliding with each other. Investigations into those incidents showed near collisions to be the result of insufficient staffing combined with the presence of faulty or outdated equipment in the facility.

Since 2000, the U.S. Department of Transportation has been attempting to enact a plan that would replace outdated radar systems with global positioning technology to track aircraft. Despite this initiative, the Transportation Department inspector general issued a report in July 2012 stating that many currently operational air traffic control facilities

are deteriorating and outdated. In that report, he called on the agency to accelerate its current 20-year upgrade plan, which is slated to be complete by 2020.

The condition of aircraft operating dangerously close to each other is not caused only by understaffing or faulty equipment; aircraft can also be forced dangerously close together in the name of maximizing profits. Since the majority of airports worldwide are for-profit ventures, and profit in the modern airline industry is dependent on running at maximum capacity, there is often pressure to push that maximum capacity as far as it possibly can go. Unfortunately, such a mind-set can get in the way of good reason or safety. Running over maximum capacity can result in low-altitude midair collisions, head-on or side-on runway collisions, forced takeoffs during inclement conditions, and even incidents involving animals or individuals on the tarmac.

What Can Be Done

Modern airlines operate their business models on an assumption of airports running at maximum capacity. Unfortunately, these models often do not put safety or comfort of the passenger first. Given this assumption of maximum capacity, air traffic often exceeds what can be effectively handled through a proper ground delay program. In this process, planes are assigned positions in a takeoff queue, and the queue is run through as aircraft are able to take off.

When the ground delay program is not sufficient to maintain air traffic flow, in-flight holding patterns may be established. These holding patterns require airborne planes to circle the airport in a queue-type system similar to the ground delay program. Thus, as long as airlines are motivated by a profit motive that causes them to strive for runway maximization, passengers may be stuck with delays, holding patterns, and potentially dangerously congested runways for the foreseeable future.

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See Also: Air Traffic Control; Airline Industry; Airplane Disasters; Collision Avoidance Systems, Airplanes.

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Air Travel

Studies in air travel behavior seek to understand passengers' long-distance travel choices. Passengers make numerous choices when planning their long-distance travel. For example: Which destinations do people consider when planning their trip? Do people consider traveling only by air or consider other modes of travel as well? If travelling by air, do people search for alternatives at one airport or multiple airports? If driving to the airport, where do people park? How much are people willing to pay to fly during peak travel periods? A better understanding of how long-distance travelers make these and related choices helps airlines, airports, government agencies, financial institutions, and other decision-making entities evaluate infrastructure investment alternatives, marketing initiatives, operational strategies, and numerous other proposals.

The types of research questions that are investigated often depend on the decision makers' perspectives. Airlines are generally focused on maximizing net revenue through attracting new customers and retaining current customers while ensuring safe and efficient operations. In contrast, airports and government agencies are generally focused on predicting demand for existing and proposed transportation alternatives. A broad range of proposals may be considered and may include new infrastructure (for example, constructing a rail line to a secondary airport or constructing a new runway), landside operational improvements (for example, building a new parking facility), or the introduction of new taxes, credits, or other policy instruments.

Data

Given the different perspectives among decision-making entities, it is not surprising that the data used for analysis also differ. Within aviation, the strong operational focus has resulted in decision-support models based almost exclusively on revealed preference data. Revealed preference data capture actual passenger choices under current and prior market conditions. Given the dynamic nature of the airline industry and the need for airlines to identify and respond quickly to changes in competitive conditions, many airlines have invested in decision-support models that rely heavily on recently observed revealed preference data.

Stated preference data are also used to understand air travelers' behavior. Stated preference data are collected via surveys that ask individuals to make hypothetical choices among different alternatives. Stated preference data are particularly useful when investigating customer response to new products or transportation alternatives. For example, in the United States, Resource Systems Group has conducted an annual survey of air travelers since 2000. This annual stated preference survey has been used by airlines to assess the potential of new or enhanced products (for example, cabin service amenities, baggage fees, and customers' willingness to pay for shorter connection times). Government agencies have also used this stated preference panel data to investigate changes in passenger behavior after 9/11.

Methodologies

Some of the most popular statistical techniques used to model air traveler behavior studies include regression, count, time series, and discrete choice models. The selection of a particular model depends on the objectives of the research and available data. For example, regression or count models can be used to represent the number of purchases made for a flight or for multiple flights serving the same market (or airport-to-airport pair). Time-series methods can also be used in this context to account for trends, seasonality, and other fluctuations in demand.

Discrete choice methods differ from the techniques above in that they incorporate information about how individuals make tradeoffs among different attributes when making a choice among a set of alternatives. For example, when deciding which

mode of transportation to take to the airport, passengers may make tradeoffs among time, cost, and convenience associated with different alternatives. When deciding which flight to purchase, passengers may make tradeoffs among the prices, departure times, level of service (nonstop versus connecting), and other flight attributes.

Research Directions

Multiple factors have contributed to the current state of the airline industry, including the emergence of online travel agencies (OTAs) that facilitate the comparison of prices across airline competitors, the increased market penetration of low-cost carriers (LCCs), industry consolidation, and the introduction of new ancillary fees. All of these factors have influenced current research in air travel behavior.

Within the airline community, these changing market dynamics have led to interest in using discrete choice models to forecast demand for revenue management (RM) systems. Conceptually, choice-based RM methods use data that effectively track individuals' purchase decisions. This could potentially include the menu of choices customers viewed prior to purchases. That is, in contrast to traditional booking data, online shopping data provides a detailed snapshot of the products available for sale at the time an individual was searching for fares, as well as information on whether the search resulted in a purchase (or booking).

The availability of Internet data is leading to research on how information about competitors' products and prices can be integrated into demand forecasts. This is viewed as important, as approximately 60 percent of online leisure travelers purchase the lowest fare they can find. Understanding how customers search and purchase online is an active area of research, as is developing models that incorporate individuals' willingness to pay for product attributes, particularly with respect to competitors' offerings.

Understanding the influence of social media and mobile devices on air traveler behavior is another active area of research. Social media sites enable travelers to share their experiences. Future travelers can use these sites to gather recommendations on where to travel, which modes of transportation to use to reach the destination, which sites to visit once they are at the destination, etc. Mobile devices

provide the opportunity to send real-time information to travelers. This information can include real-time airport parking availabilities, automated baggage tracking, and communication of flight delays. This information allows customers the ability to alter their travel plans.

In the late 2000s, many airlines started creating new products and ancillary revenue streams. New fees were introduced to check bags and reserve coach seats. In addition, many existing ancillary fees were increased (for example, fees for redeeming mileage award tickets, on-board checked pet fees, unaccompanied minor fees, in-flight entertainment fees, food for sale). The impact of these fees on air traveler behavior is currently not well understood. For example, are customers sensitive to baggage fees and will people fly on a nonpreferred carrier to avoid these fees? Do customers view seat displays when they are selecting their itineraries and will they choose a different flight (or a different carrier) if only middle seats are available to reserve for free? Understanding these and related questions are another active area of research that has been of interest to both airlines and government agencies. Government agencies are interested in ensuring that ancillary fees are clear to consumers at the time of purchase. Government agencies are also interested in quantifying potential dilutions to tax revenues (many ancillary fees are not subject to taxes in the United States).

The impact of industry consolidation on consumer welfare and regions served by small airports is an example of ongoing research that has been of particular interest to government agencies and airports. In recent years, service to smaller airports has been reduced (or eliminated). In part, this is due to increased fuel prices, which has made it unprofitable for airlines to operate regional jets into these areas. Airports and small communities are developing strategies to quantify the economic impacts of these service reductions and to evaluate different proposals for mitigating these negative impacts. For example, should a small community offer financial incentives to an airline for maintaining air service, or would it be better to initiate bus service to a major airport hub instead?

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See Also: Air Passenger Carriers; Airline Flight Reservation and Ticketing Systems; Airline Industry; Airline Marketing; Airline Passengers; Aviation, Commercial/Business; Economics of Air Travel; Travel Choice.

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Air Travel Regulations, History of

When Orville and Wilbur Wright made the first successful powered airplane flight in North Carolina on December 17, 1903, they heralded a new age of human transportation. People had been going aloft in hot-air balloons for over a century, especially in Europe, but the capacity of balloons to carry significant numbers of passengers efficiently for any real distance was limited. Within 20 years of the Wright brothers' achievement, however, that had changed, and aircraft were carrying supplies, packages, and people.

Notable accidents, incidents of mismanagement, and air traffic confusion, however,

necessitated planning of air service and air routes as well as professional air traffic control. Burgeoning airlines also had to learn how to efficiently move passengers with ease and safety. As such, the planning and policy of air traffic dovetailed with the transportation expansion that had begun in the United States and Great Britain with railroads, and with the regulatory age of the American Progressive Era.

World War I, which began just 11 years after the Wright brothers' first flight, proved the ability of aircraft to carry heavy loads and multiple people. While they lacked any real tactical doctrine, British and German air forces flew bombers on missions that were the great ancestors of the 1,000-plane raids of World War II. By the end of the war, however, planes were graduating from multiwing to single-wing designs, and aeronautical designs were enabling the construction of stronger craft.

The immediate postwar years saw the barnstorming days of aviation. Pilots, most trained in the war, put on air shows, carried bags of mail, and, depending on the capacity of their aircraft, could carry a passenger or two from place to place.

Navigation was rudimentary, with pilots using cheap compasses or flying low enough—rarely more than 500 feet up—to follow roads on the ground. Lack of plane instruments meant all flying was VFR (visual flight rules) even in bad weather. Crashes were plentiful.

First Regulations

The U.S. Congress passed the Air Mail Act of 1925 (also known as the Kelly Act), authorizing the federal government to let contracts for air-mail delivery. With 80 percent of stamp receipts going to airmail carriers, the federal government was effectively subsidizing the start of an American airline industry. The Department of Commerce handled what little regulation went with the 1925 act.

Federal aviation regulation followed the precedent-setting legislation of the American Progressive Era. During those years, roughly 1900 to 1916, the U.S. Congress approved regulation of the food and drug industries, workplace safety, and child labor.

In 1926, recognizing the need for more regulation, Congress passed the Air Commerce Act. It required regular inspection and maintenance of aircraft, fuselage and wing markings for recognition,

altitude separation in flight, and knowledge and physical exams for pilots. It also tasked the Commerce Department with the construction of airfields and the implementation of takeoff and landing procedures and air traffic control systems. The Department of Commerce created its own Aeronautics Branch to handle the new responsibilities. In 1934, the Aeronautics Branch became the Bureau of Air Commerce.

Increased passenger traffic led inevitably to increased fatal crashes in the 1930s. In the United States, more than 100 people died in accidents, including one that killed famed Notre Dame football coach Knute Rockne in Kansas in 1931. Other celebrity air crash deaths in the 1930s included New Mexico Senator Bronson Cutting in 1935 and filmmaker Martin Johnson in California in 1937. Global air fatalities topped 200 in the 1930s.

In 1938, Congress passed the Civil Aeronautics Act, which created the Civil Aeronautics Authority (CAA). The CAA would regulate air rates (the federal government had been doing something similar with railroad freight rates since 1887), regulate air routes; investigate aviation accidents, and look for ways to increase air safety.

Two years later, President Franklin Roosevelt split the CAA into two agencies: the Civil Aeronautics Administration (still the CAA) and the Civil Aeronautics Board (CAB). The CAA took responsibility for air traffic control (previously a state responsibility in most airport towers), pilot training, and air routes; the CAB handled safety regulations and accident investigations.

The CAA quickly set about planning for airfield modernization programs. In 1944, with the end of World War II imminent, the CAA submitted a report called the "National Airport Plan." Congress approved it in 1946 with the passage of the Federal Airport Act. It authorized the expenditure of \$500 million over the next seven years to update airfield runways, taxiways, lighting systems, and other essential airport systems. The legislation was updated to varying degrees through 1970.

Disaster Speeds More Regulation

On June 30, 1956, a Trans World Airlines (TWA) Lockheed Constellation and a United Airlines DC-7—both four-engine, propeller-driven aircraft (the Constellation with a distinctive tri-rudder design)—left Los Angeles Airport within

three minutes of each other. The TWA, Flight 2, was bound for Kansas City, the United, Flight 718, to Chicago. The TWA plane flew at 19,000 feet, and the United aircraft was 2,000 feet above it at 21,000 feet.

As both aircraft neared the Grand Canyon, they flew into rough weather and clouds. The captain of TWA 2 requested permission to climb to 21,000 feet, but air traffic controllers denied the request, given that United 718 was at the same altitude. The TWA captain asked to get 1,000 feet above the clouds and go on visual flight rules (VFR). Air traffic control (ATC) then assumed that both aircraft would be able to see each other. With both planes on VFR, air controllers had no further responsibility to monitor the craft.

At about 10:30 A.M., the planes collided over the Grand Canyon. The DC-7 hit the Constellation's tail, and its propellers ripped open the TWA plane's body. The Constellation's tail severed and began to fall; the front of the plane dived nose first into the canyon. The United flight also plummeted, hitting the top of a nearby mesa. One hundred twenty-eight people died.

The crash prompted a massive \$250 million overhaul of the nation's air traffic control system. The federal government also responded with the creation of the Federal Aviation Administration (FAA).

In 1958, Congress created the FAA, which took over responsibilities from the CAA in stages. Under President Lyndon Johnson, the FAA became the Federal Aviation Administration in 1967 and became part of the presidential cabinet-level Department of Transportation (DOT). At the same time, the CAB became the National Transportation Safety Board, still tasked with investigating accidents.

The FAA continued updating ATC systems, establishing the Air Traffic Control Systems Command Center, the Central Flow Control Facility, the Airport Reservation Office, the Air Traffic Service Contingency Command Post, and the Central Altitude Reservation Facility in 1970 to deal with increased airline traffic and passenger usage.

Air Traffic Controllers' Strike

Air traffic controllers working for the FAA sought unionization in 1968. The Professional Air Traffic Controllers Organization (PATCO) became their bargaining agency. After failing to receive an acceptable new contract in 1981, more than 12,000 of the

15,000 PATCO members went on strike, grounding 35 percent of the nation's daily air traffic.

President Ronald Reagan, recognizing the economic consequences of grounded commercial flights, gave the air traffic controllers 48 hours to return to work. When they did not, he fired them. FAA supervisors and military air traffic controllers stepped in to keep U.S. air traffic moving. PATCO eventually dissolved; air traffic controllers did not have union representation again until 1987.

Airport Physical Maintenance

The FAA also has control of the physical standards and maintenance of American airports. It oversees such areas as firefighting and rescue squads at airports, runway lighting systems, runway debris cleanup, and signage. It also looks for ways to mitigate wildlife strikes, that is, aircraft hitting birds, bats, or even turtles on runways. Who can forget pilot Chesley Sullenberger successfully ditching his US Airways Airbus A320 in the Hudson River after hitting a flock of Canada geese on takeoff from New York's LaGuardia Airport in 2009?

The FAA also analyzes growth patterns in airline usage and, based on projections from that information, it looks at current capacity limitations of airports. It then suggests plans for building and renovation projects to meet future needs.

Among its long list of tasks, the FAA is also responsible for reducing aircraft emissions and limiting "noise pollution" from aircraft, especially over residential areas. Airport building designs must be environmentally sensitive, and the FAA must provide relocation assistance for people being moved due to airport renovation projects.

Air Terrorism

The first apparent act of air terrorism occurred on October 10, 1933, when a nitroglycerin bomb blew the tail off a 10-seat United Airlines Boeing 247 over Chesterton, Indiana. The plane crashed, killing all seven of the passengers and crew. The incident remains officially open, but investigators quickly suspected a Chicago gangland connection. An investigation diagram published in 2011 by *chicagomag.com* suggests that the bomb was placed amid some blankets in a baggage compartment near the rear of the plane. Two passengers fell from the plane when the tail fell away. They and the tail wreckage landed some 50 feet away from the main

fuselage. The bomb may have been intentionally exploded, or someone trying to secretly transport the device may have hidden it and it exploded prematurely. Regardless, air travel had entered the age of air terrorism.

The Web site *aerospaceweb.org* lists 88 air incidents caused by onboard bombs; 56 of these caused 2,790 fatalities (not counting ground fatalities on September 11, 2001). At least six of the bombings were presumed motivated by insurance payoffs to beneficiaries of the bombers (as was depicted in the popular 1970 movie *Airport*). Most of the other incidents had political motivation, either by agents of some political movement or by lone bombers acting for a political cause.

The most notorious air terrorism incident is, of course, the 9/11 attacks on New York and Washington, D.C. Members of the radical Islamic jihadist group Al Qaeda boarded four United and American Airlines aircraft on September 11, 2001, hijacked them, and flew them toward their targets. Two of the aircraft smashed into the Twin Towers of the World Trade Center in Lower Manhattan, New York City. They ignited fires that caused the buildings to collapse. Terrorists flew another into the Pentagon building in Washington, D.C.; another group was apparently flying to a Washington target when passengers overthrew them and flew the plane into the ground near Shanksville, Pennsylvania, rather than allow the terrorists to reach their objective. Total fatalities were near 3,000, both on the aircrafts and on the ground.

Prior to 9/11, the worst case of air terrorism occurred on June 23, 1985, when members of a Sikh separatist group known as Babbar Khalsa planted a bomb in the forward baggage hold of an Air India Boeing 747. The bomb exploded when the aircraft was over the Atlantic Ocean just south of Ireland. The plane decompressed and fell apart, killing all 329 people aboard. Other members of Babbar Khalsa intended to bomb another Air India plane scheduled for takeoff from Tokyo, but their bomb went off on the ground, killing two baggage handlers.

Just as infamous was the December 21, 1988, bombing of Pan Am Flight 103, a Boeing 747, over Lockerbie, Scotland. American and British investigators determined that Libyan radicals had set the bomb that killed 270 people, including 11 people on the ground.

Responding to the Threat: Air Marshals

In 1961, after a series of hijackings in which Cuban émigrés, or expatriates, diverted American commercial flights to Communist Cuba, President John F. Kennedy announced that sky marshals, whom he called “border patrolmen,” would be randomly flying on passenger flights to deter further incidents. (President Kennedy also directed that flight deck crews lock the flight deck doors and keep the keys with them.)

The number of skyjackings rose to more than 75 by the late 1960s, prompting the U.S. Customs Service, which oversaw the air marshals program, to train nearly 1,800 new marshals. However, the program was seen as ineffective, and the number of marshals in service reportedly dropped to near 30 in the early 1980s.

In 1985, members of the radical Palestinian group Hezbollah skyjacked TWA Flight 847 and diverted the plane to Beirut, Lebanon. They held it for a 17-day siege in which one American died. The incident prompted President Reagan to again build up the air marshals service and add agents to international flights.

Decreased skyjackings in the 1990s caused the air marshals program to flag once again, but 9/11 changed that. In a fear-driven reaction to the al Qaeda attacks, Congress created the Transportation Security Administration (TSA) and placed it within the new cabinet-level Department of Homeland Security. With new budgetary allocations, the TSA reportedly hired nearly 4,000 air marshals.

Airport Security

Air marshals, however, were never the only defense against air terrorism, and airports in the 1960s began rudimentary efforts to prevent weapons from being taken aboard flights. The most noticeable security additions at U.S. airports, as well as around the world, in the 1970s were metal detectors. Before entering boarding areas, passengers were required to pass through the detectors. Frequent flyers became accustomed to the ritual of removing their watches, eyeglasses, and belts as well as emptying their pockets of change to avoid setting off the detectors.

As in other facets of air security, 9/11 upped the ante. For months after the terrorist attacks, Americans saw armed National Guardsmen at airports, and they had to affirm that their luggage had never

left their possession since arriving at the airport. After passengers caught radical Islamist Richard Reid trying to light explosive in his shoes in a post-9/11 flight, air passengers also became accustomed to removing their shoes for inspection before entering boarding areas.

Although luggage had been X-rayed for many years, by 2012 American passengers were becoming concerned over random or required subjection to sensitive full-body scans that could reveal privacy-invading images.

The TSA sees these and other measures as “layers” of security. The agency, in fact, has 20 such layers: intelligence; customs and border protection; a joint terrorism task force; no-fly lists and passenger prescreening efforts; the vetting of crew members; Visible Intermodal Protection and Response (VIPR), trained units fielded to examine trains, ferries, cars, and other modes of transportation that could serve as conduits of terrorists and weapons to airports; explosive- and chemical-sniffing canines; officers trained to detect suspicious behavior; travel document checkers, checkpoints, and transportation security officers; baggage checks; transportation security inspectors; random employee screening; bomb appraisal officers; air marshals; federal flight deck officers on aircraft; flight crews trained in terrorism responses; law enforcement officers; hardened cockpit doors; and alert passengers.

The layers overlap. The TSA proclaims the following on its Web site:

Each one of these layers alone is capable of stopping a terrorist attack. In combination their security value is multiplied, creating a much stronger, formidable system. A terrorist who has to overcome multiple security layers in order to carry out an attack is more likely to be pre-empted, deterred, or to fail during the attempt.

Israel, the target of Islamist, Arabic, and Palestinian attacks since it became a nation in 1948, has long been the acknowledged master of airport and airline security. *International Policy Digest* reports that at Tel Aviv’s Ben Gurion Airport, Israel employs a vast array of techniques—from constantly operating television monitors and scans of vehicles and passengers to patrolling armed guards, some of them in plain clothes. But Israel places a premium on interviews with people arriving at airport parking



NASA and the Federal Aviation Administration began using this lunar excursion module facility built for the Apollo program as a general aviation aircraft crash testing facility in 1972. At the Impact Dynamics Research Facility, aircraft swing on cables in the 400-foot-high structure to create controlled crashes that help researchers improve airplane safety and passenger survival rates.

areas and with passengers either arriving or departing by plane. The interviewers are well trained and encouraged to follow “gut instincts” that might be alerted by suspicious behavior or body language. Allegations of racial or ethnic profiling do not deter the security experts.

In Europe, the European Commission, European Aviation Safety Agency, and EUROCONTROL jointly manage airplane and airport security. The combined agencies work much like the FAA and TSA in the United States. EUROCONTROL is committed to a “Single European Sky” initiative, which endeavors to seamlessly integrate air traffic standards across Europe. Similar agencies work to coordinate air security in Asia.

In Africa, however, airport and airline security remain problematic. In December 2009, the arrest of a Nigerian who tried to detonate explosives as his plane from Amsterdam landed in Chicago ignited concerns about African airport security. Both the United States and the European Union were concerned about substandard equipment and practices at African airports. At the time of the failed attack,

the *Wall Street Journal* reported that the European Union had forbade at least five African airlines from flying into Europe, and only one U.S. airline serviced sub-Saharan Africa, all because of safety concerns. The TSA has endeavored to work with African airports and airlines to improve coordination.

Open Skies

Security concerns aside, the U.S. Department of State has put together an initiative to facilitate broader air commerce between the United States and the rest of the world. From the early days of mail transport to modern passenger conveyance, civil air travel has always been about commerce.

According to the State Department, open skies agreements

... expand international passenger and cargo flights by eliminating government interference in commercial airline decisions about routes, capacity and pricing. This frees carriers to provide more affordable, convenient and efficient air service to consumers, promoting increased

travel and trade and spurring high-quality job opportunity and economic growth. Open Skies policy rejects the outmoded practice of highly restrictive air services agreements protecting flag carriers.

As former Secretary of State Hillary Clinton said,

Work to “democratize” aviation continues to allow millions more Americans the opportunity to fly to international destinations each year and for countless foreign tourists to visit our country.

The State Department estimates that an open skies agreement can generate as much as \$720 million for each of any two terminal points in the United States and overseas.

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See Also: Air Passenger Carriers; Air Traffic Control; Air Traffic Flow Management; Airport Security; Collision Avoidance Systems, Airplane.

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Aircraft, New Large

In the 21st century, airlines and aircraft manufacturers have been building new large aircraft that weigh over 1 million pounds, cost billions of dollars to manufacture, and can carry between 500 and 1,000 passengers. The Federal Aviation Administration (FAA) calls airplanes like the Boeing 747-400 and the Airbus A380 New Large Aircraft (NLA). The NLAs have significantly wider wing spans, taller tail sections, longer fuselages, heavier taxiing weights, and the ability to transport large number of passengers.

Airlines believe that NLAs will allow them to make larger profits and reduce operational costs by carrying more people in fewer airplanes. As the NLA industry expands, it is having substantial impacts on existing airports and terminal operations, particularly individual passenger processing facilities. Many airports will need major facility improvements to handle NLAs, with the majority of the changes being expensive upgrades to meet FAA Design Group VI standards for most New Large Aircraft.

The Federal Aviation Administration, NLAs, and Airports

Most existing airports will have to address operational challenges to accommodate the new generation of NLAs on the airside and on the terminal side of the airport, and if they are not successfully resolved, they might prevent NLAs from operating at many airports. Forced upgrades will evidently be more expensive for older, crowded airports without any room left for expansion. Airbus suggests that upgrading airports may not be such a monumental task, claiming that the cost of upgrading existing airports to accommodate larger aircraft and their expanded passenger capacity reaches the hundreds of millions of dollars, but building new

airports will cost billions of dollars. According to this rationale, using NLAs is still more economical, even if an airport has to absorb the cost of adapting existing infrastructure.

The impacts of the NLA on airports affect airside and passenger terminal planning. The airside issues focus on airfield geometry or the size and separation of taxiways, runways and aprons, which the large dimensions of the NLAs will impact. The dimensions of the NLAs also impact system capacity and the structural design of the airfield pavement. These are crucial operation issues for the airport system.

Airside: Runway Issues

In its report titled *Impact of New Large Aircraft on Airport Design*, the FAA states that all airlines will be affected by NLAs if they choose to allow them to fly in and out of their airports. The airside impacts of airport accommodation for NLAs include geometric design of runways and taxi ways. The number of arrivals and departures on a runway during any hour depends on the mix of aircraft that use the runway. If the mix includes one or a few NLAs, the capacity will be lower than at times when the mix is made up of smaller aircraft. Large NLAs also produce wake vortices that may be a danger to planes flying right behind them.

The Federal Aviation Administration establishes runway requirements for airplanes. The A380, the first aircraft in FAA Design Group VI, has a wingspan of nearly 262 feet, and airports that serve the A380 will have to meet FAA requirements for this category as well as for runway and taxiway widths. Runway-to-taxiway and taxiway-to-taxiway separations will also need to be increased.

The NLA will impact runway design, including length, width, shoulders, blast pads, and stop ways. The aircraft weight has a great effect on the runway length. The greater the total weight (operating weight empty plus payload plus fuel) of an aircraft, the longer are the takeoff and landing distances. Longer stage lengths mean more fuel, increased weight, and longer takeoff distances. With its massive body weight, an A380 needs to operate on a longer runway to perform safely.

The U.S. Department of Transportation says that when airplanes are taking off and landing, the air traffic management requires a longer separation between pairs of successive aircraft when the first



This 2011 view from inside the terminal at Washington-Dulles International Airport shows a double-decker Air France Airbus 380 with two passenger bridges, numbered A20 and A22, attached at different levels for faster passenger transfer.

aircraft is a large and heavy airplane. Two NLAs rarely will take off or land as a pair, and the NLAs would have to be scheduled to avoid peak hours to ensure the maximum runway capacity for the busiest periods at the airport. FAA Advisory Circular 150/5325-4 sets forth detailed methods of calculating runway length and the calculations match the NLAs' runway length requirements with the B747-400, implying that any airport that can accommodate a B747-400 will require no further modification of runway length.

NLA Scheduling

Aircraft scheduling and capacity planning are meant to enhance gate efficiency and profits, and NLAs impact both. To avoid high passenger volume, airports can schedule NLAs to land or take off during off-peak hours, but this is contrary to the hub-and-spokes system, which is one of the results of the deregulation of U.S. airlines. Before hub-and-spokes, airlines operated with point-to-point routes

that often were not cost efficient. The hub-and-spokes system concentrates traffic in one airport as a major hub and collects passengers from smaller national airports known as the spokes; the gathered passengers are flown from the major hub to another major hub. Off-time flights also conflict with overseas time slots.

Emergency Plans

The Federation Aviation Administration design standards for airport emergency plans are spelled out in Aviation Regulations and Advisory Circulars, especially FAA Advisory Circular 150/5200-31. The increasing presence of NLAs makes it necessary for certain areas of airport operations to be reviewed, including fire protection and equipment and emergency procedures. The size and physical characteristics of NLAs determine the composition of the rescue and firefighting equipment at the airport. Airport firefighters will need longer ladders and other specific types of equipment to fight fires in the multiple-occupancy-level NLAs.

New Large Aircraft carry 20 to 30 percent more passengers and require airports to have additional emergency equipment, supplies, and personnel to respond to an emergency. The U.S. Department of Transportation predicts that if airports practice a full-scale emergency plan drill once every three years, the airports that serve NLAs will experience a significant increase in the number of participants and the possibility of chaotic situations.

Landside and Terminals

The high passenger capacity of NLAs eases the airside operation congestion but paradoxically creates terminal and landside congestion that may force airports to double the size of their waiting lounges and increase ticket-processing capacity. Airlines will have to expand baggage handling and customs areas and widen car park and taxi waiting areas as well and still might not even be able to handle the surges of arriving and departing passengers.

New Large Aircraft feature double-decker designs that will impact airport design and operating requirements. To keep competitive airline schedules and restrictive takeoff and landing slots, double-decker airplanes like the A380 are designed to connect three passenger bridges to meet the 90-minute turnaround demand. Many existing

terminals will have to be structurally modified to use upper-level bridges.

Plans for new airports and expansions at existing airports already take the proposed NLAs into consideration, but these aircraft may be able to operate at some facilities with modifications to taxiways and operations. The FAA identified five main issues related to the NLA and their compatibility with airport terminals. One of the issues is the number of gate positions needed for NLAs. Providing exclusive use gates for NLAs is very expensive because of their dimensions and the need for large amounts of physical space. Terminal configuration is an important component of modification or building for NLAs.

Another issue is the design and sizing of the departure, or gate, lounge, the buffer where passengers wait to board their flight. New Large Aircraft feature a passenger capacity up to 64 percent greater than older-generation airplanes like the 747. New Large Aircraft have motivated airlines to create ways of economically and efficiently accommodating passengers in the departure lounge. More passengers mean more baggage and higher flows of both passengers and baggage in the terminal. New Large Aircraft have made it necessary for airlines to formulate plans to incorporate new technologies to facilitate baggage check-in, security checks, customs, immigration, and baggage handling.

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See Also: Air Passenger Carriers; Air Travel; Airline Industry; Airport Gate Assignment Problems; Airport Passenger Terminals; Airport Planning; Aviation, Commercial/Business; Economics of Air Travel; Next-Generation Airports, Federal.

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Aircraft, Regional Jet

Regional jets (RJs) are turbofan (a type of small jet engine)-powered airliners that are capable of short- and medium-range flights. Regional jets are produced in Russia, Germany, Canada, Brazil, Japan, the Netherlands, the United Kingdom, and the Ukraine. Given the diversity of countries that produce these vehicles, it is not surprising that they come in a variety of sizes. Regional jets come in three sizes with anywhere from 27 to 130 seats, differentiated by how the seats are situated in the passenger cabin: three abreast, four abreast, and five abreast. Early RJ technology was first developed in the Soviet Union. Once Western observers recognized the potential of the technology, it was adapted to meet the needs of Western markets. Once adapted, RJs changed air travel by fundamentally altering the paths people travel through the sky by focusing on the fuel efficiency and takeoff power granted them by their

turbofan engines. Due to poor public perception of RJs, airliners have been forced to address issues such as legroom and other amenities. However, despite public relations issues, regional jets remain a cornerstone of the airline industry.

History and Development of Regional Jets

Over the course of the 20th century, social forces increasingly called for the development of light airplane technology. This resulted in the development of faster, smaller aircraft that would enable certain segments of the population to establish weekly commutes via aircraft. Aviation in the first half of the 20th century was dominated by prop planes, which are airplanes that are pushed forward by propellers affixed to either their nose cones or their wings. The advent of turbofan (or fanjet) technology following World War II revolutionized air travel. The term *turbofan* refers to a gas turbine engine that takes mechanical energy from combustion and a ducted fan. The mechanical energy from the turbine then accelerates air rearward to propel the aircraft forward.

The first vehicle that could be considered a regional jet was the Soviet Aeroflot Yakolev Yak-40. This jet was first built in the Soviet Union in 1967. The Yak-40 was used extensively throughout the Soviet bloc and Europe; it was also used in a number of Soviet-allied countries outside Europe. The Yak-40 was essentially a shortened jet with engines on either side of the fuselage and one affixed to the tail. It also featured an integrated tank that provided fuel for each engine and a cabin with seats five abreast. Despite the success of the Yak-40 in the Soviet bloc, it did not meet American or western European needs. The Yak-40 was designed to service areas with less than average air traffic; for this reason, it was little more than a shortened jet with fewer seats. American needs, in contrast, required craft that could move as many passengers as possible over short distances with as great a fuel efficiency as possible, as opposed to moving a few people over great distances.

The need for smaller, more fuel-efficient jets in North America expanded considerably after 1978. That year, the U.S. Airline Deregulation Act phased out the Civil Aeronautics Board with the objective of creating an air transportation system that would be more reliant on market forces. Due to deregulation, airlines were able to create many shorter



A Brussels Airlines British Aerospace 146 (BAe 146) regional jet landing at London Heathrow Airport in 2010. The BAe 146, while no longer made, remains especially popular with European airlines for service between small European cities, as regional jets allow for bypassing of larger airport hubs. As of 2013, regional jets like the BAe 146 were the only service option at 484 world airports.

routes to replace the few longer routes that existed previously. Prior to deregulation, airlines operated from a “hub-and-spoke model” in which all passengers were required to go through a few large airports and then travel to their final destination through feeder routes. Regional jets allowed for direct flights from city airport to city airport; thus passengers were able to bypass hubs. After deregulation, many regional airlines were created that specialized in the use of regional jets.

The first regional jet to be specifically designed for Western use was the British Aerospace 146 (BAe 146). This model was built between 1983 and 2001 in the United Kingdom by British Aerospace. The BAe 146 was specifically calibrated to serve travelers who wished to fly from city-center to city-center. As a result, the BAe 146 was designed to minimize noise and maximize takeoff performance. British Aerospace based much of the marketability of the jet on the fact that it was much quieter than its competitors and marketed the plane under the name *Whisperjet*.

Though manufacture of the BAe 146 was discontinued in 2001, it remains in service by some of Europe’s most notable airlines. This jet is widely used in small city-based European airports by airlines

including CityJet, Swiss European Air Lines, Brussels Airlines, Airlink, and Lufthansa. The jet comes in three sizes (BAe 146-100, BAe 146-200, and BAe 146-300). This plane is also known for its high degree of versatility, and it has been modified for purposes such as firefighter tankers, troop transports, and service as one of Queen Elizabeth’s luxury jets.

Contemporary Use of Regional Jets

The number of passengers serviced by regional jets doubled between 2000 and 2010 for a total of 159 million passengers. Over the past decade, RJs have proven to be critical to the airline industry’s strategy of attempting to efficiently match demand with seat capacity, thus avoiding empty seats. Another reason airlines favor RJs is because they make it possible for larger airlines to outsource to smaller carriers, thus taking advantage of the lower paid workers who are employed by those smaller carriers. At the time of this publication, regional airlines provide the only service at 484 airports.

Regional jets are not without their problems. While highly reliable and safe, RJs have both real and perceived issues. The transition to regional jets was at its highest and most popular within the industry in the 1990s. Since then, customers, especially frequent

fliers, have started to demand more than these traditionally spartan aircraft have offered. RJs are often criticized for being bumpier and experiencing a greater level of cabin noise from their engines. Additional complaints have been leveled because these planes are too small to facilitate either first or business classes or because they do not offer hot meals. In response to these complaints from frequent customers, some airlines have responded by transitioning toward larger regional jet models to minimize these most common size-related concerns.

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See Also: Air Passenger Carriers; Air Taxis; Airline Deregulation Act of 1978; Airline Industry; Airport Hubs; Economics of Air Travel.

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Aircraft, Very Light Jet

A very light jet (VLJ), as defined by the National Business Aviation Administration (NBAA), is a jet airplane approved for single pilot operation and with a takeoff weight of 10,000 pounds or less. VLJs, also known as microjets, generally have four to six passenger seats, can be piloted by one or two individuals, and are the smallest and least expensive type of jet aircraft on the market. VLJs are intended for the private aviation market and are best suited for use between noncommercial airports because they are able to take off and land from shorter runways than commercial airlines. There was enthusiastic support for the VLJ leading up to and immediately after introduction of the

first working planes in 2007, which were predicted by some to revolutionize the airline industry, but this enthusiasm has since been tempered by the difficulties of making this type of plane safe and economically viable, and many manufacturers who planned or introduced VLJ models have since ceased production of them.

Origins

In the early 2000s, many articles were written predicting that the VLJ would revolutionize air transportation, at least for business class customers, by facilitating jet air taxi services that would combine the convenience of a private, point-to-point air service (allowing the customer to avoid the hassles of using commercial airports and scheduled flights) with the speed of jet aircraft. However, the history of VLJs is marked by large quantities of hope and hype, followed by disappointment as the actual VLJs did not live up to the world-transforming potential that had been imagined for them. The first working VLJ was the Eclipse 500, developed by Eclipse Aviation in Albuquerque, New Mexico. The plane received provisional certification from the Federal Aviation Administration (FAA) in July 2006, and the first Eclipse 500 was delivered in January 2007 to David Crowe and Jet-Alliance, a shared-jet operator in California. At the time, VLJs were heralded by many as the wave of the future, and in 2007 the FAA predicted that 5,000 VLJs would be in use within the next 10 years.

Safety Issues

The Eclipse 500 was plagued with mechanical problems, and in June 2008, the FAA gave an emergency order that all Eclipse 500 planes be grounded. The precipitating incident was a June 5 incident at Midway Airport in Chicago, in which the throttle on a nearly new Eclipse 500 jammed as the pilots were attempting to land the plane, operated by Jim-sair Charter and Management. The FAA ordered inspection of the Eclipse 500's throttle lever mechanisms and investigation of another flaw, a computer error in the plane's controls that appeared to be the cause of the pilot's losing control of one of the plane's engines.

The design and production of the Eclipse 500 had been plagued by many difficulties, and in 2008 Calvin Scovel, inspector general of the Department of Transportation, accused the FAA of rushing the

plane through the certification process while it still had serious safety concerns, including malfunctions of the cockpit displays, falling wing flaps, and delivery of erroneous stall warnings. One major change, introduced relatively late in the design process, was switching engine types. Originally, the planes were intended to use Williams engines, but those engines proved to be too underpowered to allow the plane to meet FAA standards, and Pratt & Whitney engines were substituted. The change in engines required other design changes to reduce drag, increase the size of the fuel tanks, and meet lightning strike standards.

The experience of flying a VLJ is different from that of flying either a large jet or a small propeller plane, and Barbara Burian and Key Dismukes highlight some differences that should be considered when training pilots accustomed to other types of aircraft to fly VLJs. One obvious difference is the fact that many VLJs will in fact be flown with only one pilot (although the plane design may allow for two pilots), so particular attention must be devoted to the resources that will be available to the single pilot and how they could best be used (for example, a passenger could handle and fold charts). A single pilot is subject to many concurrent task demands and must therefore be particularly aware of workload management, including maintaining situation awareness, prioritizing tasks, and using autopilot effectively.

Most VLJs include much advanced cockpit technology intended to make the pilot's task simpler, but this equipment can actually increase the cognitive load on the pilot, as he or she must learn how to monitor the different systems, understand how the plane performs in different automation modes, and know how to locate resources quickly on a multi-function display. Because many potential VLJ pilots are experienced in flying planes with much lower maximum speeds, the increased speeds of VLJs compared to small propeller planes also increases the cognitive load because decisions must be made more quickly.

The National Business Aviation Administration identifies risks specific or crucial to VLJs, as opposed to corporate jets, due to the much lighter weight of the VLJs. These include wake turbulence encounters, convective weather encounters, wind shear, high-altitude upset, and mountain wave encounters. In addition, VLJs present flight patterns

somewhat unusual for air traffic controllers because they fly at relatively low altitude and are slower than commercial jets but faster than small aircraft such as a Cessna 140. Finally, several manufacturers have proposed safety devices to compensate for the possibility of mechanical failure while in the air, including the "whole-plane parachute" and rotor blades that can operate without power to provide a safe descent.

Production Difficulties

As the Eclipse 500 went into production, demand proved to be less than expected, making it impossible for the company to achieve economies of scale. Many of the expected purchasers were start-up air taxi operators such as the Florida air taxi service DayJet, who were creating a new (and unproven) business model based on this new type of airplane; for instance, DayJet placed orders for 1,400 planes, but eventually took delivery of only 28 (and ceased operations in 2008). Ultimately, Eclipse Aviation produced only 259 planes and filed for Chapter 11 bankruptcy in November 2008. Eclipse Aviation was bought by Eclipse Aerospace, a coalition led by Mason Holland, in August 2009, and in 2010 the new company announced it would deliver the first of a new model of plane, the Eclipse 550, to a customer by the fall of 2013.

Current Models

The Phenom 100, a twin-engine VLJ produced by Embraer, is the rare exception in the VLJ market—it was introduced on the market in July 2007 and remains in production today. The Honda Aircraft Company began production of the HondaJet, a twin-engine VLJ, in November 2012. Several other manufacturers have also announced or actually produced VLJ models, but most have since cancelled the line or gone out of business entirely. These include Adam Aircraft (the AdamJet), Aviation Technology Group (the Javelin), Avocet Aircraft (the ProJet), Piper Aircraft (the PiperJet), and Diamond Aircraft Industries (the D-Jet).

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See Also: Air Passenger Carriers; Air Taxis; Aircraft, Regional Jet; Aircraft Design; Aircraft Manufacturing; Airline Industry; Aviation, Commercial/Business..

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Aircraft Design

Aircraft design is an actively developing category of industrial design that encompasses mechanical, electrical, ergonomic, and chemical engineering. Aircraft design incorporates four broad areas of aeronautics development activity: (1) aerodynamics, (2) propulsion, (3) structures and materials, and (4) stability and control. Each is linked to the others, often in multifaceted and highly integrated ways.

Aerodynamics

Concern with airflow across surfaces and the principles of drag and lift are tied to the amount of power a given aircraft's engines need to deliver. The more aerodynamic the aircraft's surfaces are, the less drag is produced, and therefore the less work that must be done to provide thrust and lift. Less work means less fuel is consumed for a given flight maneuver, thereby allowing for longer flights from a given amount of fuel.

Maneuverability of the aircraft also derives from its aerodynamics. Flight surfaces must be designed with the inherent capacity for the desired stability and course alteration. Surfaces can also be designed with trim capability—for example, a wing can gain

added trim capabilities by virtue of an aileron, the bladelike hinged flight control surface typically installed in the trailing edge of the wing.

Within the domain of aerodynamics, designers must decide if the aircraft will be used primarily for subsonic or supersonic flight. This factor dictates the priority of building in various aerodynamic features. Some supersonic aircraft are designed with multiple transforming flight surfaces—for example, the "swing wing," which gives the pilot the ability to select wing configurations for optimal handling at different speeds. Among the more notable examples of such swing-wing aircraft historically is the F-111 fighter, manufactured by General Dynamics in the 1960s.

Engineers use wind tunnels and simulated wind tunnel programs to determine the optimal streamlining configuration for a given airfoil profile of a wing, fuselage, and so on. The ideal of streamlining is based on the path traced by a "massless particle" moving with the flow of wind around the aircraft mass.

Another area of design concentration is radar detection avoidance, or stealth, which can be achieved both by shaping aircraft surfaces to diffuse and deflect radio waves and by integrating low-reflectivity materials into surface fabrication.

Propulsion

Designers working in the domain of propulsion are concerned with power, reliability, durability, fuels, and the issue of exhaust and emissions. Engines must provide sufficient thrust for the aircraft to develop lift; they must operate effectively in various weather and atmospheric conditions and at different altitudes and aircraft attitudes; they must be designed with consideration of how to use available fuel mixtures to achieve a range of goals having to do with cost, noise, pollutants, exhaust visibility, and ease and stability of fuel handling. Decisions need to be made based on priorities that can include the amplitude and speed of power delivery versus fuel efficiency, power versus noise control, and power versus toxic exhaust.

In regard to piston engines, which are still widely important in general aviation, aircraft designers are making progress toward achieving high performance against the coming changes in fuel standards. Some of these new standards will be driven by raw cost factors, but others are driven by the concern over reducing or eliminating lead from aviation gasoline.



Plumes of colored dye flow over a 1/48-scale model of an F-18 fighter jet in a water tunnel used for determining optimal aircraft design at NASA's Dryden Flight Research Center.

Each alteration in fuel chemistry introduces changes in lubrication, corrosion, and horsepower—all vital components of propulsion design.

Jet engine designers, on the other hand, are hard pressed to devise new prototype and production models that will operate at reliably high standards while using completely new fuel mixtures. The driving force of this change is the environmental imperative to reduce the emission of greenhouse gases and various toxic substances such as sulfur dioxide and an array of chemical by-products of combustion of jet fuel additives. These additives are used to achieve a variety of important engine-preserving

tasks, such as corrosion reduction, thermal stabilization, static electricity dissipation, inhibition of fuel icing, and combating the growth of engine-fouling fungi and bacteria.

In contemporary aviation, the practices and mandates of such regulatory bodies as the U.S. Environmental Protection Agency (EPA) have become integral to prudent design, manufacturing, and operations standards and procedures. Rules from EPA regarding noise abatement; materials handling, recycling, and disposal; and engine exhaust limits, among others, must be taken into account during the conception and incorporation of aircraft design innovations.

The most widely used propulsion systems in aviation to date have featured propeller, turbo-propeller, rocket, and jet technology. Additional advances in propulsion may result from ongoing research and development in such categories as turbo-electric engines, which use very high-efficiency energy-source-to-fan transfer; rotating cylinder engines, which can help aircraft achieve vertical takeoff and landing; reaction engines (e.g., the Sabre) that combine conventional rocket technology with a mode that uses supercooled oxygen scooped from the atmosphere; and one or more energy sources that provide an alternative to traditional aviation gas (e.g., hydrogen fuel cells; plasma, nuclear, or solar photovoltaic systems).

Structures and Materials

The typical dichotomy in the domain of structures and materials is the tradeoff of strength and weight. Throughout the history of aircraft design, there have been periods when adding raw engine power was the default choice over the lightening of materials in order to gain performance. During other periods, most of the emphasis was on designing with technologically advanced materials such as aluminum and aluminum alloys, which could deliver great strength while greatly reducing the weight of the aircraft—thus cutting the need for more power.

The use of aluminum alloys was not simply a matter of substituting the material in place of steel; rather, the whole design and construction of the aircraft had to be reworked due to key metallurgical differences, such as the high sensitivity of aluminum to heat. However, by experimentation with various alloys and through heat tempering

and other treatments, engineers were able to make aluminum the material of choice in much of aircraft design.

In recent years, the use of composite materials has gained much attention and ever-increasing experimentation and application. Synthetic fibers, such as aramids, along with carbon fibers and other types of filament materials, can be manufactured into a variety of laminates or into a matrix that also combines ceramics, epoxies, polymers, and other ingredients. For more than four decades, materials science has made strides in fine-tuning mixtures of such ingredients and adjusting the combinative processes to develop end products that can greatly aid aircraft designers in replacing metal components with far lighter—and stronger—components.

Issues such as durability, conductivity, shear resistance, and many other performance factors of composite materials are now available for study via computer simulation, as a fairly robust database of experimentation has been compiled. Although not exhaustive, this simulation process can and does save aircraft designers valuable time in developing new applications that use these materials.

Design improvements also influence the economic practicality of various aircraft categories. For instance, far higher levels of reliability in engine construction have yielded flight durability and safety indices that provide for the broad-scale use of two-engine models in long-distance commercial jetliner fleets where formerly four-engine models were the accepted standard. At the other end of the size and scale spectrum, the development of “very light jet” (VLJ) aircraft in recent years was spurred more by market forces than by sheer technological advances; the niche for single-pilot private jets is one that has yet to be fully exploited.

Stability and Control

Increasingly, design for stability and control involves aircraft design engineers in the discipline of computer science and even artificial intelligence. This is the domain of aircraft design where the machine–human interface is most in evidence and where change and innovation are perhaps most vital. Ergonomic information is extremely useful in the design of cockpit gauges and other data displays, controls, and communications equipment, all of which must be integrated into the most

natural-feeling configuration possible. Not to be overlooked is the wealth of information gleaned from a century of human flight; designers have come a long way but still have to incorporate calculations of human pilots’ capacities, limits, and inevitable errors.

Redundancy of control is essential to design; it is just as important as accounting for various tolerance curves for stresses to the aerodynamics, engine and ancillary mechanical systems, and material structure of the aircraft. As new combinations of engines, fuels, trim systems, navigation, and structural components are designed and built, the basic handling features of a given aircraft are altered. It is critical to stay connected to human pilot feedback about such features, in addition to using the best computer simulations available. Both computer-generated engineering data and data derived through the use of flight simulators are invaluable to the design process.

Modular Design

Among the more futuristic transportation concepts that aircraft designers are beginning to work with in real time is the idea of modular design. At its most ambitious, this term refers to placing a passenger or group of passengers in a capsule that itself is transferred between modes of transport that can include road, rail, sea, and air. In some ways, this is akin to the development of container transport in the shipping of cargo.

For modular function of this type to be practically achieved in aircraft design, the passenger capsules must be able to affix to a fully independent flying wing type of aircraft, or to something similar that incorporates all essential aircraft components except the internal fuselage passenger cabin that has been customarily used. Theoretically, this type of modular transport, if standardized and widely adopted, could yield substantial savings in weight, materials, maintenance, loading and boarding time, terminal space, and intermodal handling.

Regulatory Issues

Although designers and engineers may prefer to develop new materials, components, and systems according to strictly mission-driven, mechanical-challenge, and pilot-preferred criteria, the reality of the modern flight environment imposes a range

of detailed and explicit airworthiness regulations and test protocols that must be met before new aircraft design prototypes can go into production. An example of a change in the regulatory structure advocated by aircraft owners, pilots, engineers, and mechanics is the Small Airplane Revitalization Act of 2013.

This legislation is intended to provide for faster, smarter testing and certification of new aircraft designs to augment safety and performance for VLJ and other prototypes and to streamline certification (and potentially reduce costs) of similar upgrades to existing aircraft. As adopted by the U.S. Federal Aviation Administration, the act holds the potential for a less cumbersome path to airworthiness certification for individuals and companies building and operating smaller, simpler aircraft to achieve better aviation metrics while also sustaining economic viability.

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See Also: Aeronautical Decision Making; Aeronautics; Aircraft, New Large; Aircraft Engine Emissions; Aircraft Manufacturing; Airplane Navigation Systems; Automated Landing Systems, Airplane; Emerging Technologies.

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Aircraft Engine Emissions

Aircraft engine emissions have been the subject of technological innovation, commercial influence, environmental concern, and political and regulatory activism for decades. The various categories of aircraft engines yield different types of emissions, many of them directly harmful to human beings, others deleterious to the balance of atmospheric gases on which we depend. Two vectors are driving the changing nature of these engine emissions today: the technological drive for gains in energy efficiency, materials reduction, and power performance increases, and the environmental priority to cut greenhouse gas production and curtail the release of toxic agents.

Engine Types and Fuels

Thrust for forward propulsion and to develop lift in airplanes is provided by a range of engine systems designed around one of two main types: piston-driven propeller models, and reactive or jet engines. "Avgas" is the term used to refer to the aviation fuel used in piston engines. Jet engines burn jet fuel, a kerosene-based, low-volatility formula similar to diesel. Avgas—in contrast to automotive gasoline, where legislation reduced and ultimately removed lead—still includes lead in most formulations, specifically tetraethyl-lead, which has proven toxic qualities.

Jet fuels incorporate a vast array of additives that provide a range of important performance-enhancing and protective functions; but each of these may be suspect in terms of carcinogenic or other toxic outcomes.

Makeup of Emissions

With its lead content (used to increase octane levels and support better performance), avgas has been shown in various studies to be a factor in increased blood-lead levels in children residing near general aviation airports where many small aircraft take off

and land. There are some 20,000 such airports in the United States alone. The U.S. Environmental Protection Agency (EPA) has stated: “Emissions of lead from piston-engine aircraft using leaded avgas comprise approximately half of the national inventory of lead emitted to air.” The EPA has also noted as recently as 2010 that “serious health effects occur at much lower levels of lead in blood than previously identified” and that there is no known safe level of lead exposure.

Kerosene-based jet engine fuel, also called aviation turbine fuel, or ATF, embodies a group of fuel types that are chemically tuned to provide a range of performance standards for use in different atmospheric conditions and operational functions, as well as safety standards for storage, handling, and use. In recent decades, more adjustments to ATF have been tested and adopted with an eye to cutting air pollution and greenhouse gas emission. Synthetic fuel formulas, as well as biofuels, have been important in this regard. One example from among the key pollutants from ATF is benzopyrene, which is often found in smoke from other sources as well, such as cigarettes, forest fires, and petroleum combustion. This soot-carried chemical is absorbed through the skin and by inhalation; it is strongly linked to lung cancer and is highly suspect in many other cancers, as it has powerful mutagenic, or DNA-altering, qualities.

Both types of aircraft fuel emit hydrocarbon or greenhouse gases, in particular, carbon dioxide, nitrogen oxides, sulfur oxides, and water vapor. Besides atmospheric warming, these chemicals can also contribute to acid rain, ocean acidification, and health threats.

Standards and Monitoring

Airplane engines as air pollutant sources are monitored and regulated as a mobile source, along with sea vessels and land surface transport. Both the chemical makeup of the fuel used by these mobile sources and the design and quality of machining of the engines are main factors in emission type and volume. In particular, the European Organisation for the Safety of Air Navigation (EUROCONTROL) requires a form of aircraft performance model known as a Base of Aircraft Data (BADA) license, which also includes mandates on emissions assessment and provides licensees access to the Advanced Emission Model (AEM) computing system for purposes of calculating emissions.

Takeoff and landing (LTO) emissions are typically analyzed separately from non-LTO emissions. Likewise, there are varying guidelines based on altitude. Standards of the International Civil Aviation Organization (ICAO), for example, are used by EUROCONTROL for the calculation for activity below 3,000 feet of altitude, while its BADA standards guide the above-3,000-foot cycle. The AEM system is able to differentiate between six distinct LTO phases of operation: taxi out, take off, climb out, approach, landing, and taxi in.

Testing Alternatives

Strides have been made in recent years to develop alternative fuels whose chemical makeup will reduce the emission of greenhouse gases and toxic materials. These fuels have now been employed by both military and civil aviation well beyond early-prototype experimentation; some airlines now promote their use of biofuels on an everyday basis in at least part of their fleets as a marketing issue, for example. These include United Airlines, which has made much of its November 2011 application of an algae-based biofuel (blended with 60-percent regular jet fuel) on a commercial flight from Houston, Texas, to Chicago, thereby cutting hydrocarbon emissions. The fuel was manufactured by Solazyme Corporation in cooperation with the U.S. Navy.

Researchers are advocating that the Federal Aviation Administration (FAA), EUROCONTROL, and other agencies promote faster deployment of lower emission biofuels and synthetic fuels by subsidizing their use to some degree, and also by fostering higher efficiency engine design in general. Such analysts also propose incentivizing airport–airline partnerships to develop more effective operations to reduce emissions in both the LTO phase of flight—by updating air traffic and ground layout and flow—and in the non-LTO phase by better regional coordination toward more efficient flight paths and schedules.

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See Also: Air Pollution/Air Quality; Aircraft Propulsion, New Technologies of; Airports, Environmental Issues and; Alternative Fuels; Emissions Modeling; Health Issues; Lead Pollution; Mobile Emissions; Nitrogen Oxides.

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and overhaul (MRO) is therefore one of great official scrutiny and necessary oversight. From original manufacture through years and even decades of flight service, every aircraft and its components must meet a certified set of standards that are monitored via regular specified inspections.

In the United States, the Federal Aviation Administration (FAA) designates as certified those aeronautical repair stations that meet the standards and inspection milestones administered through its Flight Standards Service. Additionally, when major design changes occur in civil aviation aircraft types or fleets, the FAA deploys its Aircraft Certification Service to test and approve the changes and to disseminate information updates pertaining to maintenance and safety.

Inspection Regime

The field of aviation safety—with its strict quantification and qualification regimes for mechanical fitness of aircraft; readiness of pilots, flight crews, and ground support staff; and intensive research into the causes and prevention of flight failures—has generated a robust structure of aircraft maintenance rules, metrics, reporting mandates, and enforcement mechanisms.

These regulations have evolved over the course of nearly 100 years, and the tangible results include such progress as the steadily declining incidence of fatal air accidents. The Continuous Airworthiness Maintenance Program (CAMP), established and administered under oversight of the FAA, features several levels of routine and detailed inspections. Each is done at a specified milestone based on a number of variables including flight hours, takeoff-and-landing cycles, or time elapsed since the initial operation of the aircraft.

The most fundamental and frequent type of inspection in civil aviation, commonly termed Check A, is typically accomplished overnight at an airport hangar or even at the terminal gate. A Check B CAMP inspection, usually done several times each year, tends to take an aircraft out of service for up to three days. The Check C routine is yet more involved, requiring considerable teardown of the aircraft; this necessitates an inactive period of up to two weeks and is repeated every 14 to 24 months. Finally, Check D, undergone about once in five years, entails nearly total teardown and can immobilize the aircraft for two months.

Aircraft Inspection and Maintenance

Maintenance is essential in keeping airworthiness levels high in airplanes and in their pilot support systems. The field of aircraft maintenance, repair,

Because these levels of aircraft inspection and overhaul necessitate major ground-based infrastructure investments, they must be taken into account during airport planning. They are characterized by capital-intensive fixed assets and high operating costs due to the need to employ highly skilled staff. Therefore, aircraft maintenance is a major component of both airline operations and airport administration.

Similar systems of inspection, component overhaul, and repair are in place outside the United States. For example, the European Aviation Safety Agency (EASA) operates a similar regime for civil aviation carriers doing business in the European Union.

Changing Market Conditions

Many major airlines operate their own in-house MRO facilities and operations. However, a plethora of stand-alone MRO companies provide service to every type of aircraft system, assembly, part, and repair situation, often with specialty maintenance lines that use the most advanced technology and that are staffed up to the highest skill set in the industry. Most airlines therefore find it convenient and cost-effective to contract a great proportion of their maintenance work. These contracts, along with the ever-changing dynamic of technological challenges and innovation in aircraft design and performance and the constant reviews and upgrades to the mandated regulatory inspection cycles, are the drivers of the MRO industry.

Due to swift and far-reaching changes in the regional airline business, MRO companies are undergoing a transition in customer base and in the economies of scale they must consider in order to remain competitive. Additionally, when major airlines are involved in increased subcontracting to regional carriers, those regionals must maintain additional aircraft models. Further, MRO companies that seek stronger bonds with national airline operators know they must add facilities in new locations.

Industry observers in general note that this focus on size, scope, and flexibility will not necessarily influence the basic metrics of a quality MRO provider—reliability, efficiency, and cost. However, the outsourcing of MRO functions is not without controversy. Among the more complex issues is the reality that MRO takes place in a global marketplace



In-house maintenance staff for All Nippon Airways (ANA) of Japan inspecting a jet engine at Tokyo Haneda Airport in April 2012. As of 2013, maintenance, repair, and overhaul (MRO) for jet turbine aviation was a \$65-billion industry worldwide.

affected by widely varying national and regional regulatory, inspection, and political structures. In the United States, the FAA undertook a major analysis and upgrade of its oversight of outsourced MRO following the 1996 crash of ValuJet Flight 592, an event that focused great scrutiny on the outsourcing of MRO. Critics of the FAA's efforts, such as spokespersons for the Professional Aviation Safety Specialists and the Aeronautical Repair Station Association, have stated that the FAA's inspection and documentation practices are in many cases largely redundant and therefore wasteful. In other cases, critics say, the FAA's policing lags behind or misses entirely the accomplishment of proper certification and timely monitoring of many subcontracted MRO operations.

Cooperation among some of the major global aviation regulatory bodies, such as the FAA and EASA, has increased in tandem with the expansion of MRO outsourcing—the goal being to standardize,

as much as possible, local MRO oversight and the resulting aviation safety and reliability. Complicating the achievement of such progress are issues like compliance with standing and in-negotiation labor agreements with union and nonunion workers, cost and tariff differentials between countries where MROs are based, and interagency regulatory regimes such as those between national aviation authorities and a host country's environmental, economic, and industrial-practices administrations.

Another change in the marketplace is the makeup of the civil aviation fleet itself. More than 6,000 jets and turboprop aircraft will retire from service over the next decade, according to industry projections—but the fleet will still grow by 3 percent annually. While carriers have been reducing, and continue to reduce, the number of various aircraft types flown, this pace of aircraft retirement portends a nearly unprecedented influx of new vehicles. It is both a challenge and a major opportunity for the MRO industry and its employees.

Scale of the Industry

According to a 2013 study by the Aeronautical Repair Station Association (ARSA), the global market for MRO services to the jet turbine sector of civil aviation is approximately \$65 billion and growing. The study pegs engine overhaul at some \$26 billion—the single largest segment—followed by component maintenance at about \$17 billion and heavy airframe maintenance at approximately \$13 billion. Line maintenance, which is most typical of a CAMP Check A service level, rings up to about \$10 billion.

The ARSA study finds that more than 4,000 MRO companies certified by the FAA are operating in the United States alone, accounting for about 196,000 employees engaged in the maintenance, repair, and overhaul of civil aviation aircraft. Most of these companies are small to medium in size; these firms account for about one-fifth of all employees. Another 45,000 MRO workers are directly employed by the air carriers to staff their in-house maintenance operations.

Additionally, there are more than 65,000 employees in the parts manufacturing and distribution sector of aviation, closely allied to the MRO field, who have many transferable skills and techniques. ARSA notes that these levels of economic activity and employment are signs of a robust and resilient

industry, especially when considering the economic struggles that began in 2008 in the United States.

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See Also: Airplane Disasters; Airport Planning; Aviation, Commercial/Business; Emerging Technologies; Federal Aviation Administration.

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Aircraft Maintenance Training Programs

Aircraft maintenance safety issues are particularly critical because they involve the safety of flight crew, passengers, and aircraft maintenance technicians. Errors in maintenance can cause damage or

destruction to aircraft and have a cost in people's lives and the profit of the company. The Federal Aviation Administration (FAA) through Advisory Circular (AC) 120-72 presents guidelines to develop maintenance resource management (MRM) training programs to improve aircraft maintenance safety.

Errors made by maintenance personnel are considered latent errors, meaning that they may lie hidden from view and undetected until sometime later during flight or after a number of flight hours. Some of the aircraft maintenance errors are using wrong parts; electrical wiring discrepancies; loose items left in aircraft; inadequate lubrication; access panels not secured; fuel/oil caps not secured; gear pins not removed before departure; parts damaged on installation; equipment not installed or missing; improper fault isolation, inspection, or testing; and preventative maintenance procedures overlooked.

Human conditions such as fatigue, complacency, and distraction are important because 80 percent of maintenance errors involve human factors. In an effort to improve safety by reducing human error, FAA AC 120-72 was created to provide background information on MRM. An MRM training program can provide the necessary training to assess and change behaviors to work more safely and to reduce human error by improving communication and safety in aircraft maintenance.

The "Dirty Dozen"

An important aspect of MRM is the "Dirty Dozen," or the 12 most common negative factors that influence a mechanic's performance. Recognizing the Dirty Dozen will identify the chain of events leading to an error and provide ideas on how to develop safety nets to prevent accidents. They were created by Gordon DuPont of Transport Canada after a string of maintenance-related accidents in the late 1980s and early 1990s. The first six are "lack of" communication, resources, assertiveness, awareness, teamwork, and knowledge. The second six are "abundance of" pressure, stress, norms, fatigue, distraction, and complacency in the workplace.

First is lack of proper communication, which will result in poor work quality, important information being misinterpreted, and higher levels of stress. Barriers to good communication include passive listening, no/poor feedback, nonstandard terms (acronyms), inappropriate communication

methods (verbal/nonverbal/written), vague or ambiguous information, and late information. These barriers exist between technicians, supervisor to technician, pilot to technician, and different maintenance departments. Safety nets that can be used to prevent problems are use of checklists and worksheets, proper "turn overs" to other technicians to complete the work, and an attitude of never assuming anything.

Second is the lack of resources, which includes technical manuals, parts and materials, tools, proper lighting, shelter from the elements, heat or cool temperatures, technical support (engineering), people, time, and ground support equipment. Resource safety nets involve ordering all necessary parts in advance and verifying they are on hand before starting a maintenance job, or arranging for a loan of parts and equipment when needed. Standards must always be maintained, and when in doubt, the aircraft must be declared unairworthy or be grounded.

Third is lack of assertiveness. Aircraft technicians need to be assertive when something is wrong to ensure a problem is not overlooked. A three-step assertiveness method is to be accurate, bold, and concise. Barriers to assertiveness may involve rank or position differences in authority, peer pressure, and a lack of confidence due to lack of knowledge or experience. Assertiveness safety nets involve recording all work in the aircraft log book and signing only for what is serviceable. When in doubt, it should be written up in the book, and technicians should refuse to compromise their standards.

Fourth is the lack of awareness of important job-related conditions and events. This often occurs when there is insufficient communication, fatigue or stress, task overload or underload, and degraded operating conditions. Maintenance technicians may fail to think fully about the consequences of their work. The safety nets are to check to see if the work will conflict with an existing modification or repair by being aware of technical data revisions, to ask others to check their work, and to be aware of their surroundings.

Fifth is a lack of teamwork because people are not working together properly. Safety nets are for the team to discuss the what, who, and how a job is to be accomplished and to verify that everyone understands and agrees with the plan before beginning the job.

Sixth is a lack of knowledge, which can cause an error in judgment. The safety nets are to get training on the task, use current technical manuals, and when in doubt, ask for help.

The seventh item begins the concern for an abundance of pressure. Pressure is a form of stress and usually is caused by a lack of time, resources, or people to complete a task. The safety nets are to be sure the pressure is not self-induced, communicate any concerns, ask for help, and when necessary, just say no.

Eighth is an abundance of stress, which can result from personal issues, seeking approval from the boss, concerns with the weather, and having difficulty with the repair. Safety nets involve workers being aware of how stress can affect their work, pausing to evaluate the situation rationally, deciding on the best plan, resting when needed, talking about the problem with someone, having a coworker check your work, and eating properly and exercising regularly.

Ninth is an abundance of norms. These unwritten rules become pressures on a group. Ineffective norms are detrimental to organizational goals and they reduce effectiveness. Safety nets are to always use written instructions, or have them changed, and to be aware that norms do not make it right.

Tenth is an abundance of fatigue, which reduces the effectiveness of a person's ability to work. Fatigue is caused by loud noise, excessive vibration, improper lighting, change in shift hours, long work hours, lack of sleep, stress and exertion, and large temperature changes. Symptoms of fatigue are often not recognized until an error or accident occurs. Safety nets are to get enough sleep and exercise often, look for symptoms of fatigue in oneself and others, avoid doing complex tasks when tired, and have a coworker or supervisor check your work.

Eleventh is distractions, a common occurrence, yet if they occur during a critical phase they can be disastrous. Technicians should try to complete the task or unfasten the connection, mark the work as incomplete, double-check the work or have a coworker check it, go back over the last three steps when returning to an incomplete job, and always use a checklist and technical data.

The last performance factor is an abundance of complacency. Due to the repetitive nature of maintenance, a degradation of vigilance occurs. Safety nets exist to train the technician to look for and

expect to find fault and never to sign for anything the technician did not do or see done.

Conclusion

Errors can be made by anyone, including experienced technicians and in organizations previously thought to be safe. Aviation maintenance safety can improve with an aggressive MRM program that includes recognizing the symptoms of the Dirty Dozen.

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See Also: Air Traffic Controller Training; Aircraft Inspection and Maintenance; Airplane Pilot Training; Federal Aviation Administration.

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Aircraft Manufacturing

Many people had flown aircraft such as balloons that were lighter than air, but on December 17, 1903, Orville Wright made the first successful flight in an airplane that was heavier than air. It was a controlled flight of a plane powered by a small internal combustion engine. The flight lasted only 12 seconds and the plane traveled just less than 130 feet (40 meters) at Kitty Hawk, North Carolina.

Others had attempted heavier-than-air flight, but the Wright brothers invented aircraft controls that made fixed-wing flight possible. The focus of their research was on developing a reliable method of pilot control for steering the airplane and maintaining its equilibrium through the use of a three-axis control of the rotations of a craft's roll, pitch, and yaw. The roll, pitch, and yaw are similar to those of ships, which also must be controlled as they move



Wing assembly for the Boeing 747-8, an updated and extended version of the 747, in July 2009. The Boeing aircraft manufacturing company originated when Seattle lumberman William Boeing built a seaplane with Navy lieutenant Conrad Westervelt in 1914. Boeing then began the Pacific Aero Products Company, which eventually became the Boeing Airplane Company.

dynamically through the medium of a liquid fluid rather than a gaseous fluid.

Their bicycle shop in Dayton, Ohio, was where Wilbur and Orville Wright honed their mechanical skills on printing presses, bicycles, machinery of various kinds, and various motors. They came to believe that the solution to flight problems, like that of bicycles, was the establishment of stability in motion. They built a wind tunnel to refine their knowledge of flight dynamics. Developing their piloting skills with gliders between 1900 and 1903 at Kitty Hawk, they also made Charles Edward Taylor, a bicycle shop employee, a part of their team. Taylor built the engine used by the Wright brothers on their first flight.

Between 1903 and 1908 the Wright brothers continued to improve their airplanes as they sought to gain patents and contracts to build planes. On May 14, 1908, Wilbur flew the Wright Flier III with young mechanic Charles Furnas (1880–1941) as his passenger.

Ready to begin selling their invention, Wilbur went to France to quell intense skepticism that they had not made heavier-than-air flights. Flights in the Model A Flyer were very successful as Wilbur made a figure eight and circles and conducted other challenging demonstrations of his skills as a pilot in control of his aircraft. French aviation enthusiasts were amazed and flocked by the thousands to the airfield to see the show. Wilbur's flights also attracted British and German interest. The flights also gained them a test demonstration by Orville for the U.S. Army that was also successful.

While in France, Wilbur flew Edith Berg, the wife of their European business agent, as the first woman passenger on October 7, 1908. She was one of many who were passengers with him that autumn. However, tragedy struck on September 17, 1908, when army lieutenant Thomas Selfridge, a passenger on a test flight with Orville, was fatally injured. The crash was caused by a propeller that

split into pieces. It left Orville badly injured and in a long hospital recovery.

In July 1909 Orville and Wilbur delivered to the U.S. Army a two-seat airplane that could fly for an hour at an average speed of 40 miles per hour (64 kilometers per hour) and land undamaged. The plane was delivered after a series of proving flights. Their payment included a bonus for delivering a plane that could fly faster than specified in the military contract.

The Wright brothers were issued a patent on May 22, 1906, for new and useful improvements in flying machines. However, by 1908 many others were reengineering the invention or were making improvements to other ideas of the brothers. A flight by Glenn Curtiss using ailerons was viewed as not covered by the Wright brothers' patent. This disagreement led to a patent-infringement lawsuit war between the Wright brothers and companies in America and Europe. In January 1914, a federal appeals court ruled in favor of the Wrights and against the Curtiss Company.

With World War I under way and a demand for airplanes mounting, Orville sold the Wright Company in 1915. The federal government then promoted a cross-licensing agreement between aircraft manufacturers. In 1929 the Wright-Martin and the Curtiss Aeroplane companies merged to form the Curtiss-Wright Company.

World War I and subsequent wars in the 20th century stimulated technological inventions in the aircraft industry. During peacetime periods, innovations and experimental ideas were developed by the numerous civilian companies, in many cases as they converted from wartime production to civilian production. In 1908 Edson Gallaudet organized an aircraft engineering center, which became the ancestor of the General Dynamics Corporation. In 1910 he opened the Gallaudet Engineering Company, and he reorganized it in 1917 as the Gallaudet Aircraft Corporation. In 1918 it began production of the Curtiss floatplanes. It was sold in 1923 to the newly formed Consolidated Aircraft Company.

The Burgess Company began manufacturing Wright aircraft in 1911. It built modifications of Wright license agreements by adding pontoons to some Wright planes. In 1913 it delivered to the U.S. military a tractor biplane and later a Burgess seaplane. In 1916 it merged with the Curtiss Aeroplane and Motor Company.

The Thomas Brothers Company began manufacturing biplanes for the Royal Naval Air Service in 1914 in Ithaca, New York, and in Bath, England. In 1917 they merged with the Morse Chain Company to form the Thomas-Morse Aircraft Corporation. Training numerous American and Canadian pilots, they also developed new models of airplanes. The expertise in manufacturing fighter aircraft was turned to racing planes and training aircraft.

In 1910, Columbia University granted the first aeronautical engineering degree to Grover Loening. He began working with the Wright Company in 1913 but quickly grew disenchanted with its management. He then became the chief aeronautical engineer for the U.S. Army Signal Corps in San Diego, California. In 1915 he helped organize the Sturtevant Aircraft Company, which focused on naval aviation. The first Sturtevant aircraft was the Kitten, which was intended as a scout plane but developed into the M-8, one of the first American fighter planes.

In 1914 the Boland Aeroplane Company was renamed the Aeromarine Plane and Motor Company. It manufactured more than 300 military planes in New Jersey during World War I. It later improved flying-boat aircraft.

Glenn Martin built his first successful airplane in 1909. In 1911 he founded the Glenn L. Martin Company, which built the Model TT tractor-engineer trainer for the U.S. Signal Corps. In 1915 Martin hired Donald Douglas as an engineer. In 1916 the Martin Company merged with the Wright Company to form the Wright-Martin Company. However, displeased with the results, Martin moved to Ohio in 1917 where he formed a second Martin Company. He was joined by Douglas. With a contract from the U.S. Army, they manufactured 10 successful bomber planes.

In 1912, Allan and Malcolm Loughead organized the Alco Hydro-Aeroplane Company. In 1916 they formed the Loughead Aircraft Manufacturing Company which, in 1918, rolled out the 10-passenger F-1 seaplane. However, the demand crashed at the end of World War I. The company's other work, subcontracting and building Curtiss HS-2L flying boats, did not prevent the bankruptcy of Loughead Aircraft in 1921.

In 1914 William Boeing, a successful Seattle lumberman, built a seaplane, the B&W, with Navy lieutenant Conrad Westervelt. Boeing then organized an aircraft manufacturing company, the Pacific Aero

Products Company. The name was later changed to the Boeing Airplane Company.

The L-W-F Company, founded in 1915, developed a laminated wood fuselage. It also developed the monocoque fuselage, which was a major improvement over earlier fuselages.

Ryan Aviation built the Spirit of St. Louis to Charles Lindbergh's specifications in the 1920s. The company's founder, T. C. Ryan, went on to develop other aviation products, and the company was eventually merged with other companies. Historically, the pattern has been for companies to absorb one another, but for new companies to then emerge. Military contracts create wartime feasts and peacetime famines in the world of aircraft manufacture.

Most of the early civilian aviation companies disappeared. Some merged to become the giants of later decades. During the 1930s and 1940s, several new aviation companies entered the market. The Grumman Aircraft Engineering Corporation was founded in 1929. It was acquired by Northrop Corporation to become Northrop Grumman in 1994.

Modern civilian-aviation airliners developed rapidly after World War II as engineering advances in bombers such as the B-29 allowed for long-distance flight. By the 1960s, air travel was replacing railroad and steamship travel. The Boeing 747 was introduced in 1970. New jetliners were developed thereafter by Boeing (757 and 676), by McDonnell Douglas (MD-11), by Lockheed (L-1011-500 Tristar), and by other companies. The Airbus and Concorde were superliners but were eventually replaced by newer models. As aviation markets have fluctuated the pattern of corporate takeovers has continued, as has development of new models of planes. The terrorist attacks using hijacked airliners on September 11, 2001, harmed the business of commercial airlines. It also hurt sales for new airplanes, causing some business takeovers. However, airliner development has continued. One plane that attracted wide public interest was the Boeing 787 Dreamliner, rolled out in 2007, which was capable of carrying several hundred passengers. It has experienced fires from its lithium batteries, a problem that had not been solved by November 2013.

Attempts at improving airplanes have been constant since the era of the Wright brothers. At first all aircraft were civilian. The general-aviation side (small private planes) of civilian aviation has

included those companies that are able to survive by supplying the many markets including racing planes, seaplanes, cargo transports, corporate jets, bush planes, large passenger planes, and other kinds of aircraft. New private aircraft (e.g., the Learjet, the Beech Bonanza D35, the Cessna 1728 Skyhawk, the Cessna 340, the Piper PA-46-350P, the Rutan Model 33, and many other models, including non-American aircraft [e.g., the English Slingsby T.67C Firefly]) continue to come to the general aviation market to supply growing flying interests. Many are using new light composite materials as well as traditional lightweight metals.

Aviation advances in light aircraft, drones, balloons, and gliders have continued to grow, as has civilian interest in the commercial development of rockets for space travel.

Military planes have continued to advance with long-range bombers such as the Northrop stealth B-2. Transport plane development has continued beyond Lockheed's C-5 cargo plane with tactical transports. Fighter planes continue to advance with application of military spending. The research from such national security investments eventually aids civilian aviation.

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See Also: Aircraft, New Large; Aircraft, Regional Jet; Aircraft, Very Light Jet; Aircraft Design; Aircraft Inspection and Maintenance; Aircraft Propulsion, New Technologies of; Airline Industry.

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Aircraft Propulsion, New Technologies of

The common public perception is that the National Aeronautics and Space Administration (NASA) is an organization dedicated primarily to travel in outer space. However, it is likely that the organization will play an integral part in the development of the next three generations of passenger aeronautics. This influence is coming from NASA's N+3 program. This program is directed toward solving problems of environmental and social impact, including airplane emissions, sound pollution caused by passenger jets, and finding ways to utilize regional airports, which are often underused. The means to achieve these goals are being pursued by multiple teams. These teams are backed by private interests and have been granted funding by NASA to address individual aspects of the N+3 program by 2025.

Explaining N+3 Goals

In the early 2000s, NASA developed a set of research objectives known as the N+3 goals. These goals are directed toward developing the next three generations of aircraft, thus the name N+3. The N+3 goals are based on the three core objectives of reducing energy consumption, reducing noise associated with both subsonic and supersonic flight, and reducing toxic emissions. These goals were established to guide funding to organizations interested in developing the technologies that would usher in the next generation of aeronautic propulsion.

The name N+3 denotes that the goals will direct the development of propulsion technologies through the next three generations of flight technology. These goals are set in three tiers: N+1, N+2, and N+3. The N+1 goals are set to be met by the participants in the project by 2015. By this time, the participants are working to meet goals in sound reduction, toxic emissions, and fuel efficiency. Additionally, participants are expected to meet certain field length performance requirements, which require vehicles to be able to land and take off using shorter distances than possible with conventional aircraft. Furthermore, participants are expected to have their prototypes emit 60 percent less nitrogen oxide emissions and to improve their fuel burn by 33 percent. In 2015, NASA expects participant to develop craft that are 32 decibels quieter than their

2008 counterparts. Field length performance is also expected to be improved by 33 percent. Goals related to sound reduction and field length are being set primarily so that airports can be located closer to city centers.

The N+2 goals are due to be met by 2020. At that point, participants are expected to have reduced engine sound output by at least 42 decibels. Additionally, nitrogen oxide emissions are to be reduced by 75 percent, aircraft burn is to be improved by 50 percent, and field length performance is to be improved by 50 percent.

The final set of N+3 goals are to be met by 2025. By this time, engine noise is to be reduced by 71 decibels. Nitrogen oxide emissions are to be improved by better than 75 percent, and aircraft fuel burn must be improved by better than 70 percent. Finally, field length performance is expected to exploit metroplex concepts (which individuals to commute between cities in close proximity, thus having the effect of creating one large city.) by 2025; these concepts have been recognized by both NASA and the Federal Aviation Agency (FAA). By exploiting metroplex concepts, these vehicles will be able to contribute to utilization of closely spaced airports, increase arrivals and departures, and navigate congested metropolitan areas.

How the Goals Will Be Achieved

After establishing goals, the next step is to determine how they will be met. N+3 goals will likely be met in one of five ways. Participants are anticipated to meet goals either structurally by altering the design or by utilizing advanced materials. When structurally altering the design of the craft, changes may be made to reduce the weight of the secondary structure (those parts that if damaged do not directly impair the flight of the craft). Structural changes can also be made to alleviate drag issues by installing high-aspect-ratio wings, which tend to be very long and narrow and serve to grant a greater amount of lift. N+3 goals can also be met by incorporating advanced materials into the design of the craft. This may be done by including advanced structural materials and advanced engine materials into the design.

N+3 Participants

On October 6, 2008, NASA awarded research contracts totalling \$12.4 million to six private teams

that agreed to study advanced concepts for subsonic and supersonic commercial transport that could enter service in 25 to 30 years under the terms of the N+3 goals. The six teams were drawn from five private U.S. entities. The Northrop Grumman Systems Corporation specializes in unmanned drones, cybersecurity, and security systems. In working toward its N+3 goals, Northrop Grumman is focusing on environmental issues, including noise footprints and improving runway stopping distances. The Massachusetts Institute of Technology (MIT) is a private research university located in Cambridge, Massachusetts; it consists of five schools and one college. MIT is developing a subsonic fixed-wing transport aircraft. This craft will likely utilize a liquid natural gas fueled, multiple engine propulsion system. Lockheed Martin Corporation is an aerospace company with global interests and a long history of working with the U.S. government for military and civilian purposes.

Lockheed Martin is developing environmentally friendly supersonic airframes, and technologies that will reduce airport noise and emissions for the N+3 project. GE Aviation is a subsidiary of General Electric. This subsidiary is one of the top aircraft engine suppliers for the aviation industry. GE Aviation is working on technologies that will reduce environmental impact as much as possible and maximize existing regional and suburban airports toward this end as much as possible. The Boeing Company is a U.S. aircraft designer and builder serving multinational aerospace and has a long history of defense contracting. Boeing is hosting two teams. These teams are focusing on vehicle sizing, environmental conformity, risk mitigation, noise reduction, emissions, takeoff length, fuel use, and energy utilization.

The majority of effort surrounding the N+3 project focuses on developing various aspects of either superconducting electric aircraft propulsion or hybrid electric aircraft propulsion. On this topic, superconducting electric aircraft propulsion is critical because N+3 craft require extremely efficient engines in terms of mass-to-power generated. This is because engineers seek to get the greatest amount of power for the mass of the engine. Most efforts are focusing on developing turboelectric propulsion; however, efforts are made in exploring other hybrid electric technologies and other types of propulsion.



A rendering of the Subsonic Ultra Green Aircraft Research (SUGAR) Volt aircraft concept submitted to NASA by a Boeing research team in April 2010. The twin-engine plane would use hybrid propulsion combining gas turbine and battery technology.

Turboelectric research is by far the propulsion type of greatest interest to N+3 projects. Turboelectric engines are similar to conventional jet engines in that they convert mechanical energy generated by turning a fan (i.e., turbine) into electric energy to power the craft. Turboelectric propulsion systems differ from conventional jet engines in that instead of relying on two to four large fans affixed to their power source, they utilize many smaller engines spread over the entire wing area. This has several effects: in terms of power generation, it serves to provide a larger fan surface area, thus creating a greater amount of electricity.

In regard to structural design, most proposed turboelectric craft should be able to approach runways at steeper angles with less noise and require shorter runways. These feats are possible because the multiple turbine design makes engines more effective. Additionally, since engines are mounted on top of the plane, sound is dampened as lift is reduced. This sound reduction could allow for a greater number of nighttime takeoffs and airports could be located closer to city centers. Furthermore, the need for less runway space allows for

greater utilization of regional airports and would further encourage the construction of airports in highly developed city centers. These features could be incorporated into craft featuring other types of propulsion, but they are most prominently featured in turboelectric designs.

Hybrid Electric Technologies

Although turboelectric technologies have been favored by N+3 researchers, they are still heavily dependent on liquid fossil fuels. Hybrid electric technologies, which are within the scope of the N+3 goals, seek to either minimize or eliminate dependence on these fuels. These types of aeronautic propulsion systems were flown as early as 1957. However, this type of experimentation has seen great resurgence in recent years, in part due to the N+3 goals. Electric double-layer capacitors are a type of next-generation high-power battery. These super batteries may take the form of fuel cells or solar cells. Double-layer capacitors may also be paired with power-beaming technologies, which transmit electrical energy from a power source to its goal without conductors; good candidates for power beaming include microwaves or lasers. The benefits of electric-based propulsion systems include the safety gained by excluding liquid fuel, fuel efficiency, and reduction or elimination of toxic or global warming-contributing gases..

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See Also: Air Travel; Aircraft, New Large; Alternative Motor Fuels Act of 1988; Emerging Technologies; Nitrogen Oxides.

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Airline Deregulation Act of 1978

Much of the history of transportation in the United States has been characterized by government regulation, which has been considered necessary since the heyday of the railroad industry. In 1936, Congress extended the Railway Labor Act of 1926 so that airline labor issues were brought under that same umbrella of government oversight. In 1938, the Civil Aeronautics Authority (CAA), which became the Civil Aeronautics Board (CAB), was assigned responsibility for approving airline routes and rates and for certifying carriers within designated markets.

By the 1970s, however, there was considerable support for deregulating the transportation sector. The first major move in the route toward deregulation began with bipartisan support that resulted in the passage of the Airline Deregulation Act of 1978 (S. 2493). The act was signed into law (P.L. 95-504) by President Jimmy Carter on October 24, 1978. Upon signing it, Carter stated that the act would accomplish the twin purposes of fighting inflation and lowering the price of airfares so that they would be more affordable for the average American.

Airline officials were elated that deregulation was ushering in a period in which they could establish or eliminate routes according to the dictates of the market, allowing competition to flourish without government interference. Even before the Airline Deregulation Act of 1978 was signed into law, Alfred Kahn, the chairman of the CAB, had been overseeing the early stages of deregulation, working toward the ultimate goals of amassing higher profits for airlines while reducing fares by as much as 50 percent. The Airline Deregulation Act was

not intended to compromise airline safety, which continued to be regulated by the Federal Aviation Administration (FAA).

Background

In 1926, Congress passed the Air Commerce Act, which gave the Department of Commerce the authority to regulate the operations and safety of airlines. In 1938, the Civil Aeronautics Authority, the forerunner of the CAB, was established to concentrate those functions within a single agency. The CAA comprised five members who worked with the agency's administrator to carry out the agency's mission. Safety oversight was assigned to the three members of the Air Safety Board. By the late 1930s, there was mounting concern over airline safety issues, the financial health of airlines, and complaints about existing inequities within the transportation sector. In 1940, under President Franklin D. Roosevelt, the Civil Aeronautics Authority became the Civil Aeronautics Board, and the CAB took on the responsibilities of both the CAA and the Air Safety Board. The CAB continued to exercise the authority to limit the number of airlines operating in the United States. In 1938, there were 16 so-called trunk airlines providing air service.

By 1974, the number of trunk airlines had dropped to 10, even though the CAB had received 79 applications from airline companies desiring to open new businesses. Two years later, William T. Coleman, Jr., the secretary of transportation, and Senator Ted Kennedy (D-MA) cowrote the Air Transportation Regulatory Reform Act of 1976, which attempted to initiate the process of deregulating the airlines. However, the bill failed to garner sufficient support for passage. In 1978, with the support of the Carter administration, Senator Howard W. Cannon (D-NV) introduced a new airline deregulation bill, and the Senate passed the Airline Deregulation Act of 1978 by a vote of 82–4. Due to considerable bipartisan support, the House also passed the bill by an overwhelming majority (356–6).

Public Law 95-504

The Airline Deregulation Act of 1978 (P.L. 95-504) provided for government regulation of airline activities to be phased out over the following years. As of December 31, 1981, CAB control over airline routes was essentially abolished. The following month, airlines were granted control over interstate and

overseas routes according to an automatic entry system. Airlines gained control of their own rate plans on January 1, 1983. The bill established 1985 as the date by which the Civil Aeronautics Board was likely to be eliminated. Upon elimination, any federal power that still resided with the board was to be distributed among the Department of Justice, the Department of Transportation, and the U.S. Postal Service.

Unless considered a predatory action under CAB guidelines, airlines were allowed to decrease fares up to 50 percent. In order for a route to be considered active, an airline was required to provide air service five days a week for 13 weeks during a 26-week period. By the fall of 1978, 1,295 routes had been declared dormant under this provision. Airlines responded by filing papers to have them reinstated. The bill also included protections for smaller communities by guaranteeing service for a decade after the deregulation process began. Certain stipulations continued to govern procedures for labor disputes. Airline officials were required to place strike-related funds in the Mutual Aid Pact. No operating costs could be transferred from the fund for 30 days, but 60 percent of operating expenses could be used during a period that began 30 days after the strike was initiated and ended eight weeks later. Any carrier experiencing a strike was required to submit to arbitration. In cases of bankruptcies and major financial losses that resulted from deregulation, nonmanagement employees were to be protected for 10 years through guaranteed salary parity.

Impact

In 1978, when the Airline Deregulation Act cleared Congress, there were 36 certified passenger carriers in the United States. Within six years, that number had climbed to 123 carriers. By February 1979, the airlines had created 150 new service routes, and plans for other routes were under way. Even though deregulation was designed to spur the economy, the intense competition that accompanied deregulation spelled financial disaster for many airlines. According to *Airlines for America*, which lists bankruptcies and service cessations for all airlines located in the United States and in American territories, two airlines filed for Chapter 11 bankruptcy protection in 1979. The number of filings climbed in the 1980s, totaling 87 for the decade. The number of Chapter 11 filings dropped to 44 in the 1990s as the result of

an improved economy but rose to 54 between 2000 and 2012 as the United States experienced a major recession. Between 2001 and 2005, airlines reported almost \$28 billion in operating losses. Bankruptcies affected even large airlines, and both Pan-Am and Eastern folded. When airlines declared Chapter 11, all labor contracts and pension plans were voided. Thus, employees often faced financial disaster on both a personal and a professional level. Some airlines fought to survive by merging with other airlines. In 1987, only 74 of 245 airlines certified since the passage of the Airline Deregulation Act remained in operation. Nine major airlines continued to control 90 percent of the market, according to a report issued by Airline Economics, Inc.

As deregulation of the airlines was put into practice, airlines were ostensibly free to establish new routes and eliminate those that were not deemed profitable. However, some exceptions remained in place. One of those exceptions arose from the Wright Amendment, pushed through Congress by Texas Democrat Jim Wright. The Wright Amendment retained limits on certain airlines in order to protect them from major competitors. For instance, Love Field, which served the Dallas/Fort Worth area, was banned from accommodating flights destined for cities outside Texas except for those traveling to Arkansas, Louisiana, New Mexico, and Oklahoma. This lack of competition resulted in passengers in Texas paying as much as 75 percent more for airplane tickets than did passengers in neighboring states.

Other airlines were limited by the practice of “slots,” which was designed to limit congestion at airports by restricting the number of takeoffs and landings permissible within a single hour. The practice of slots also increased airfare because the price of tickets was increased in response to delays imposed on other aircraft waiting to take off. A third limit on airlines concerned perimeter rules, which limited the length of flights going to or coming from New York’s LaGuardia Airport and Ronald Reagan Washington National Airport in Washington, D.C., by limiting the miles flown to and from those airports to 1,500 and 1,250 miles, respectively. Application of perimeter rules also raised the price of airline tickets for passengers in those areas.

While passengers were delighted with the decrease in the price of airline tickets, many were inconvenienced by the decision to create the

“hub-and-spoke” systems that routed passengers to designated airports. Passengers also had major gripes about bad service at most airlines. Since airlines could garner higher profits from routes to major cities, passengers also complained that smaller communities were not being adequately served under deregulation. Indeed, between 1978 and 1984, the number of communities served by airline routes declined from 632 to 541. The general public blamed the federal government for increased congestion at existing airports because of the lack of federal assistance for building new airports. Airline employees also complained about the changes wrought by deregulation. With pilots and crews working longer hours and equipment not always in proper repair, the number of near-midair collisions increased. When 13,000 stressed air traffic controllers initiated a strike in 1981, demanding higher wages and a shorter workweek, President Ronald Reagan summarily fired them and issued a lifetime ban that prevented all striking air traffic controllers from returning to their jobs in the future.

Conclusion

Overall, deregulation of the airlines has been considered successful, and Jimmy Carter has earned praise for his role in initiating the process. Under subsequent presidents, deregulation spread to the railroads and the trucking industry. In 2006, within the context of discussions about reregulating the airline industry, the Government Accounting Office (GAO) issued a report on the impact of airline deregulation. The report stated that industry capacity and passenger traffic had tripled since the passage of the Airline Deregulation Act of 1978. The GAO determined that between 1980 and 2005, airfares had fallen by nearly 40 percent. Airlines had become more competitive since deregulation, but service was deemed to have improved only slightly. The conclusion of the GAO was that reregulating the industry would likely reverse benefits gained by deregulation.

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See Also: Air Passenger Carriers; Airline Flight Reservation and Ticketing Systems; Airline Industry; Airline Pilots and Crews, Labor Issues of; Airline Service Quality Modeling; Airport Hubs; Deregulation; Economics of Air Travel.

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processes that increased revenues by offering different prices to different segments of customers.

Market Segmentation

Traditionally, revenue management in the airline industry focused on segmenting business and leisure travelers. Leisure travelers typically book further in advance and are price sensitive, whereas business passengers typically book later and are less price sensitive. By segmenting these customers, carriers are able to charge passengers a price that is closer to the amount that they are willing to pay. The market can be segmented by creating different types of round-trip fare products that are tied to various fare conditions and ticket restrictions. The lowest priced fare products are often tied to advance purchase restrictions, length-of-stay requirements, and/or Saturday-night-stay requirements. For example, many of the lowest fares require a passenger to book at least 14 days in advance of flight departure and require the trip length to be longer than one day. This effectively creates a fare product that would be unattractive to business passengers. Most of the lowest priced fare products are also nonrefundable. In order to purchase a more flexible, refundable ticket (which is more attractive to business customers), the customer must purchase a more expensive ticket.

Over time, however, new low-cost carriers (LCCs) began entering the market to compete with the older legacy carriers. LCCs have different business models and approach ticket pricing differently than legacy carriers. LCCs focus on keeping operating costs low so that they can offer lower fares than legacy carriers. LCCs have simple pricing structures that use one-way pricing instead of round-trip pricing, which removes length-of-stay and Saturday-night-stay restrictions. The introduction of these simplified pricing approaches has made it more challenging for legacy carriers to charge different prices for business and leisure customers, which in turn has lowered their revenues. Both legacy and LCCs have embraced ancillary fees as a way to increase their revenues.

Pricing and Ancillary Revenue Trends

Since deregulation, average airfares have decreased. For example, after adjusting for inflation, the Bureau of Transportation Statistics (BTS) finds that average airfares decreased by 15.6 percent between 1995 and 2011. Although there are many reasons why airfares have decreased since deregulation, one main factor

Airline Fares

Before the U.S. airline industry was deregulated in 1978, the Civil Aeronautics Board controlled fares, routes, and schedules. During the regulation era, all passengers in the same class paid the same price, or fare, to fly on a route. After deregulation, carriers were able to make decisions about how much to charge, where to fly, and when to fly. The practice of offering one price to all customers changed, and carriers began implementing revenue management

is the increased market penetration of LCCs, which has led to increased fare competition. Additionally, the increased use of the Internet has led to pricing transparency. Online travel agencies such as Expedia, Orbitz, and Travelocity allow customers to quickly search the prices of multiple airlines across multiple departure dates. As a result, some studies have found that 60 percent of leisure travelers report that they purchase the lowest fare they can find. The need for carriers to remain price competitive has resulted in the development of pricing decision support systems. These systems help airlines identify when their competitors' fares change and provide recommendations on how the airline should respond to these fare changes. Airlines file fares with fare distributors such as the Airline Tariff Publishing Company (ATPCo). Airlines update their fares up to three times a day and submit over 1 million fare changes daily through ATPCo.

To remain profitable, airlines introduced new ancillary fees for services that used to be bundled into the base price of a ticket, including fees for checked baggage and seat reservations. In addition, fees for existing services increased, including fees for checking pets, redeeming mileage award tickets, and exchanging tickets. According to the BTS, from 2007 to 2011 ancillary revenues reported by U.S. carriers with operating revenues over \$20 million increased nearly threefold, from \$3.6 billion to \$9.8 billion. Increased revenues from ancillary revenue streams have also been reported worldwide.

Future of Airline Pricing

Today an increasing number of bookings are being made online, which presents an opportunity to use detailed search and purchase information to learn about customer preferences and to design products and services that better align with their preferences. For example, when a customer conducts a search on an airline's Web site, clickstream data is collected that shows what the customer searched for and whether he/she booked a ticket. Analyzing this clickstream data could give airlines a better understanding of how passengers purchase tickets. This may eventually lead to more customized pricing.

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See Also: Air Travel; Airline Deregulation Act of 1978; Airline Flight Reservation and Ticketing Systems; Airline Industry; Airline Marketing; Deregulation; Economics of Air Travel.

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Airline Flight Reservation and Ticketing Systems

Today's airlines use sophisticated software to manage passenger reservations, ticket records, and the fees and tariffs charged by airports and state and federal agencies. Due to the complexity of managing reservations, flight schedules, and layovers, airlines

were early adopters of computerized systems. The first such system, the Reservisor, was developed for American Airlines in 1946, at a time when the few computers that did exist were largely purpose-built for use by government agencies and research institutions. The Reservisor was an automated booking system, but these early computers required a team of human operators who coordinated with another staffer who answered the telephone to communicate with travel agents. Nevertheless, it proved popular and similar systems were adopted by other airlines and by hotel chains.

American Airlines continued to work on its system, replacing card files with a magnetic drum with the introduction of the Magnetronic Reservisor, and meetings with IBM in the early 1950s culminated in IBM's proposal to develop an "electronic brain" to tackle the task of managing flight reservations. The arrangement between American and IBM was formalized in 1957. IBM's work on the matter was based on the company's previous work for the U.S. Air Force, in which an early online system had been developed to coordinate communication between radar sites and fighter aircraft. The same type of teleprinters used in the Air Force project could be used in American Airlines ticketing offices, allowing elements of an airline flight reservation system to communicate with each other without the need for human operators on the telephone. The system could both verify the availability of a ticket and perform the booking on subsequent request.

The team of engineers working on the American Airlines reservation system called their work the Semi-Automated Business Research Environment, or SABRE. Costing hundreds of millions of dollars adjusted for inflation, it went online in 1960 in a dedicated data center in Briarcliff Manor, New York, and could handle tens of thousands of phone calls a day. In 1964 it assumed all booking functions for American, and in 1976 travel agents were granted access to the system. IBM developed similar systems for other airlines, such as the PANAMAC for Pan Am and Deltamatic for Delta, before creating the general purpose Programmed Airline Reservation System (PARS), initially for use on IBM System/360 business computers. The SABRE group developed its own programming language for reservation systems, SabreTalk. By the early 1980s, reservations could be made online through the Genie and CompuServe online services, followed in the 1990s by

America Online. SABRE later went on to become Sabre Holdings, a separate company from American Airlines, which today owns the Travelocity Web site.

SABRE was one of the first real-time operating systems and the first computer system of its scale to be relied on by a major industry like the airlines. Its development pioneered the use of computer systems for business functions and was a major boon to the travel industry itself. When the airlines were deregulated in 1978 and new companies entered the industry, they needed to acquire reservation systems quickly in order to compete with the established airlines. In one case, the new company Texas Air purchased the older and poorly performing Eastern Air Lines purely to acquire Eastern's System One computerized reservation system.

An early proposal by American Airlines to institute a common reservation system for the whole airline industry, one that would keep the power in the hands of the airlines rather than the travel agents, was refused by the rest of the industry because of concerns that it would invite an antitrust investigation. The first multiaccess reservation system was instead introduced in the United Kingdom, when Travicom was introduced by Videcom International in 1976, allowing travel agents to book British flights with 49 different airlines. Videcom introduced similar systems throughout the world.

Today, every airline and regional carrier has its own reservation system. Global distribution systems (GDSs) connect the major airlines with travel agencies and travel Web sites, allowing customers to book flights from point A to point B and to compare prices and other factors across multiple airlines. The GDS tracks itineraries and creates interconnectedness between the airline reservation systems but does not itself maintain inventories (the lists of all flights and all the available seats on those flights, by service and booking class). Use of GDSs makes it easier for passengers to coordinate itineraries that include flights on multiple airlines, in which case the GDS retains information about the entire itinerary, while each airline's reservation system holds the portion of the itinerary relevant to that airline. In the 21st century, SABRE—along with one of its competitors, Amadeus—functions as both a GDS and a reservation system; each functionality behaves as a separate system.

The use of computerized reservation systems has allowed for much more sophisticated reservation

systems than were used in the past or even in the early days of computerized systems. Prices are more easily adjusted, for instance, which rewards early bookers; day-of-departure business-class upgrades and standby seat-fillers fill the flight as close to capacity as possible in order to maintain the airline's profit margin. Reservation systems also track massive amounts of data, and problematic overbooking situations can be avoided by monitoring trends in this data. Flight schedules, too, can be adjusted if trends in underbooked flights are revealed.

These new reservation systems have also come with problems, notably including the delays caused by US Airways' 2007 integration of its reservation system with that of America West, an airline with which it had merged in 2005. The integrated system was unable to communicate with ticketing kiosks, requiring all passengers to check in at the counter. This situation almost doubled the number of passengers at the counter, and lines were long enough to cause passengers to miss flights. Only one-eighth of US Airways' flights departed on time during the weekend the new system was launched. In 2010, Virgin Blue's New Skies reservations system, owned by Accenture, crashed multiple times, resulting in hundreds of canceled flights and a multimillion-dollar dispute between the two companies. A subsequent system crash in 2011 required Virgin to manually process passengers and baggage, causing departure delays more than an hour long throughout the United States.

Ticketing systems use rule sets, routing maps, and data about information that affects ticketing prices (e.g., taxes and tariffs) to construct the fare in response to requests fed into the system by an agent or other software. Class of service and booking conditions affect the fare as well, and because of airport taxes, fares vary for any available city pair. The fare basis code is the set of all fare conditions. Ticketing systems don't just determine fares; they issue and store electronic tickets and electronic records of paper tickets (which are now the minority of airplane tickets).

The growth and popularity of online comparison and reservation sites like Expedia and Orbitz has led to a push in the industry to develop new reservation and ticketing systems. The industry group International Air Transport Association (IATA)—which developed industry standards for paper tickets and baggage tags and the three-letter codes used

to designate airports—has asked the Department of Transportation for permission to move away from Edifact, the computer language used for ticketing systems for four decades, in favor of the more modern XML (extensible markup language). Part of IATA's goal is to make it easier to transition to a new ticketing and distribution system, one that can tailor options and prices to the customer, in order to let the airlines compete with comparison sites. The request was filed in 2013. One complaint about the plan is that tailoring tickets to customers will require collecting personal information from them in an age when customers are increasingly concerned with privacy.

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See Also: Air Passenger Carriers; Air Taxis; Airline Fares; Airline Flight Scheduling; Airline Marketing.

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Airline Flight Scheduling

When most people fly, they do not think too carefully about airline flight scheduling—unless such scheduling directly influences their personal plans. Even in the event that personal plans come in conflict with changes in flight schedules, passengers are only rarely cognizant of even a few of the

many factors that influence airline flight scheduling. Much of airline flight scheduling is maximized through automated procedures, which are based on mathematical models. These models are incredibly complex. This article addresses only a portion of the factors included in those models. The broad scope of factors that can influence airline flight scheduling include very large-scale elements, such as weather, and major social events, such as a presidential inauguration or widely celebrated holidays (Christmas, Thanksgiving, etc.).

Not only must purely logistical considerations come into play when determining flight schedules, but staffing issues must also be taken into consideration. To operate, each flight requires a crew, including pilots and flight attendants. In terms of basic material logistics, each plane requires a certain amount of cargo, baggage, and equipment needed for safe and comfortable operation.

The subject of airline flight scheduling is not without controversy. In fact, serious allegations have been made regarding the way schedules and alterations in those schedules are typically handled. Furthermore, critics claim that precautions could be taken to prevent conflicts from occurring in the first place.

Elements

Flight scheduling is at the core of what makes our modern air travel systems work. Scheduling, and many other functions of modern air travel, must take into account departure and arrival times. Additionally, each airline possesses only so many vehicles of each model. Thus, aircraft availability must be taken into consideration in flight scheduling models.

We live in a capitalist society, and the air travel industry is likewise oriented toward capitalist goals. Within the realm of capitalist-oriented transit systems, the ultimate goal of maximizing profits is met by matching seat capacity to passenger demand. By keeping seats at maximum possible capacity at all times, airlines seek to reduce costs. For this reason, airlines focus on fuel consumption and maintenance per passenger in the name of maximizing profits. In this way, when flight scheduling takes into consideration distance between destinations, desirable flight times, operating restrictions, aircraft operating costs, and staffing considerations, airlines are able to achieve



Passengers at Charles de Gaulle Airport in Paris, France, consult a flight information display showing dozens of cancelled flights caused by the eruption of Iceland's Eyjafjöll volcano in April 2010.

their profit goals while getting passengers where they need to go.

Staffing considerations are a complex and multifactorial element of flight scheduling. The crew of each vehicle requires a number of critical personnel. These on-board personnel include pilots and flight attendants. These personnel are regulated by various interests, including corporations, federal agencies, and labor unions.

A standard flight requires two or three fully qualified pilots to fill the positions of captain, first officer, and flight engineer. The captain is the individual who actually flies the plane and is ultimately responsible for the craft. Additionally, she makes all major command decisions. She also manages emergencies with both the aircraft and the passengers. The first officer serves as the second in command of the craft. He has access to controls identical to those of the captain. Furthermore, he has the same level of training as the captain. The primary role of the first officer is that of safety; he provides second

opinions on piloting decisions and seeks to prevent pilot error. Depending on the model of the aircraft, the plane may or may not have a flight engineer. Flight engineers are fully trained pilots. Under typical nonemergency circumstances, flight engineers do not fly. Their role is to monitor the plane's instruments; in newer planes, such monitoring is performed by computerized systems. It is likely that the role of flight engineer will be phased out entirely in the near future.

Second only to the cockpit crew, flight attendants are critical to the smooth operation of the aircraft. The standard practice is to have one flight attendant per 50 passengers. By this metric, a 200-passenger plane will have four flight attendants. Flight attendants tend to the needs and comfort of the passengers and keep other aspects of the flight running smoothly. Other crew critical to maintaining flight schedules are the runway crews. These individuals prep planes before takeoff and tend to the plane's needs after landing. Their duties include, but are not limited to, refueling the plane, aiding the pilots in parking the plane, and loading baggage and other cargo on and off the craft.

There are other issues that may be taken into consideration in airline flight scheduling. Logistic concerns regarding the movement of various components must also be incorporated into plans. These include the flow of passengers from concurrent flights, concurrent cargo flows, and the movement of aircraft and flight crews through time and space. Mechanical issues, such as aircraft equipment issues and maintenance, must also be taken into consideration. Finally, issues directly relating to passengers, such as ticketing, check-in, baggage drop-off, and security concerns may also serve as important components of flight scheduling models.

The Cause of Delays

The Federal Aviation Administration (FAA) considers a flight to be delayed when it is 15 minutes later than its scheduled time. By similar FAA regulation, cancellation is said to occur when the airline does not operate the flight at all. Either delay or cancellation may occur for any number of reasons. These may include maintenance problems, staffing shortages, staff strikes, aircraft cleaning, standard maintenance, baggage loading and unloading, fueling, extreme weather (which may vary based on regional

conditions), air traffic congestion, late arrival of aircraft scheduled for subsequent flights (such an event may have a cascading effect), security issues, and glitches on behalf of the airline.

Delays in flight schedules are not universal in their cause, and their cause may vary from airport to airport. In fact, some airports consistently experience issues that are unique to that facility. Some of these issues are based on natural geography, others are based on placement of population bases or human activity centers. Due to its proximity to the San Francisco Bay, the San Francisco International Airport frequently faces delays due to fog. Similarly, Burbank's Bob Hope Airport often faces delays and other difficulties due to high winds caused by proximity to the Verdugo Mountains.

Philadelphia International Airport does not face unique issues due to its terrain but rather to its social location. The occurrence of a delay spreading from one airport to another due to late arrivals is not uncommon. However, due to its location between New York City and Washington, D.C., the Philadelphia airport frequently must cope with the fallout of cascading delays from those ports of call to a greater degree than occurs at other airports.

Controversy

There is no debating that air traffic delays are very inconvenient for passengers and crews. Additionally, they have a negative impact on the profitability and public relations efforts of airlines. The controversial element of air flight scheduling relates to the cause of delays. Some critics have argued that airlines overbook flights recklessly in the name of profit; this, in turn, causes delays. Others claim that airline errors in flight scheduling and other glitches are the cause of delays. According to a 2007 *USA Today* analysis, airline glitches are the number one cause for flight delays. This accusation challenges the common perception and claim by the airline industry that weather or heavy air traffic days (such as Thanksgiving or Christmas) are the primary cause for delays.

Such glitches may include ground crews taking too long to refuel, preventable mechanical breakdowns, and pilot shortages. Staffing shortages have been a particularly difficult problem in the modern era that has been perpetuated by high turnover. Airlines do not deny that the current system must be improved. However, they still blame weather

conditions for the vast majority of delays. If the accusations of preventable glitches reflect reality, then the delays that cause so much frustration and lost revenue to both passengers and airlines could, in fact, be solely the fault of airlines. This would be reason for significant reform.

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See Also: Air Passenger Carriers; Air Traffic Flow Management; Airline Fares; Airline Industry; Airport Gate Assignment Problems; Airports and Hubs; Aviation, Commercial/Business; Aviation, Private.

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Airline Industry

Aviation was born at the dawn of the 20th century as a result of the dedication and passion of many people, especially entrepreneurs, throughout several centuries. Up to the 1900s, most of the flying initiatives and experiments were carried out by visionaries, enthusiasts, scientists, and even military figures. One of the first recorded flights

occurred on the afternoon of September 19, 1783, in Paris, France. A hot air balloon flew for around eight minutes for a total distance of about 2.5 miles carrying onboard a sheep, a cock, and a duck. The animals survived the journey, demonstrating the existence of breathable air above the surface. Later that year, on November 21, two people—Pilâtre de Rozier and the Marquis d'Arlandes—flew over Paris for about 5 miles (8 kilometers).

In the 1800s, many other ballooning initiatives took place, mainly for leisure or entertainment purposes, although some included distribution of letters (the beginning of air postal service), all using balloons. On November 7, 1836, Charles Green and two passengers took off from Vauxhall, London, and landed in Weilburg, Germany, a total flight distance of 49.7 miles (800 kilometers) and flight time of 18 hours; on October 19 to 20, 1887, Louis Godard took off from Leipzig, Germany, and landed in Tarnow, Poland, a total flight distance of 1,181 miles (1,900 kilometers) and flight time of 24 hours.

The invention of aircraft is often credited to Sir George Cayley (1773–1857). In 1799, he advanced the concept of a heavier-than-air machine that could fly. The machine had many of the components of the modern airplane, including fixed wings and separate systems for lift, propulsion, and control.

Not without a certain degree of controversy, the first flight is credited to the Wright brothers—Orville and Wilbur—on December 17, 1903, in Kitty Hawk, North Carolina (United States). The aircraft, with capacity for one person, was airborne for only 12 seconds and flew for about 273 yards (250 meters). Despite the humble beginning, it marked the start of an outstanding adventure that would lead man to dominate the skies in the coming decades.

Prior to World War I, aviation remained in the early stages with few initiatives taking place, concentrated mainly in the United States and Europe. It is worth mentioning that the first freight commercial flight took place on November 7, 1910, between Dayton and Columbus, Ohio, and the first regular passenger air service started some years later on January 1, 1914, between Tampa and St. Petersburg, Florida, and ended on March 31 of that year. By that time, the sector was struggling with major limitations in the knowledge and development of aeronautical technology. As a result, aviation services



An Eastern Air Lines plane, promoted as part of the "The Great Silver Fleet," arrives at the Washington, D.C., municipal airport in July 1941. Eastern Air Lines operated from 1926 through deregulation in the late 1970s, finally succumbing to high costs, competition, and a significant debt load. The airline ceased operations in 1991.

were carried out with considerable limitations: aircraft had very low capacity both in terms of payload and volume, and most flights were only possible during daylight and in good weather conditions.

Throughout this period most efforts were in the transport of mail. In the first decade, however, as Camille Allaz eloquently writes in his history of air-cargo and airmail,

. . . at best, [letters] were placed on board an aircraft, which carried out a brief flight over the airfield before landing at its point of departure: one cannot therefore really describe these as *postal transport*.

During the second decade, aeronautical technology evolved enough to enable the construction of capable aircraft, and air mail route initiatives multiplied worldwide to include the United States, Great Britain, Italy, South Africa, Italy, Germany, Egypt, Sweden, and Denmark.

World War I marked a watershed in aviation history. Governments finally grasped the full potential and versatility of aircraft, which could be deployed on scouting missions, attacks, or

transport, and they massively invested throughout the war period in the development and construction of aeronautical technology. For example, in France, where there were about 600 aircraft in 1914, around 34,000 aircraft were built during the war. A similar leap would occur some decades later, during World War II, when civilian aviation activity was brought to a sudden halt and aeronautics research and development for military purposes would receive major incentives.

Between the World Wars: 1920s to 1940s

Near the end of World War I, on August 28, 1919, six aviation companies from six European countries got together to found the International Air Traffic Association, which would later become the International Air Transport Association (IATA). This organization was meant to promote and coordinate the development of international air traffic and to defend the interests of its member companies.

During the war, aviation technology underwent significant developments. Afterward, those developments spilled into the civil arena, feeding the start of numerous aviation companies for passengers, freight, and mail in many countries

worldwide, including Australia, China, Colombia, Japan, and the United States, as well as European nations. A major breakthrough for aviation was made in the United Kingdom in the 1930s with the invention of radar.

This technology could be used either on the ground for detecting solid objects (aircraft) in the air, or on board aircraft for guidance. Radar is still the backbone of today's air traffic control. Other significant improvements, but related to the air cargo business, also took place in the 1930s with the development of the first aircraft that could carry freight in the lower deck (belly). Aircraft could now simultaneously transport passengers and goods, enabling aviation companies to offer both services in the same operation.

In Europe, in the initial phase, freight was the main driver of aviation's development seen because a significant part of the continent had communication and transport networks destroyed by the war and there was urgent need for securing the conveyance of mail, bedding, medicines, and food to the affected regions. Soon after, both passenger and mail segments would grow and have an equal share of responsibility in building the sector. Interestingly, in Europe the passenger segment has always been vital, with most aviation companies having mixed transport services (for carrying people, mail, and freight) and very few entirely dedicated to the transport of either mail or freight.

This situation was in contrast with the United States, where the growth of aviation was mainly driven by the mail transport services. The U.S. Post Office Department (US POD) was closely connected with the history of civil aviation for the first decades and, due to the relatively modest level of passenger and general-freight services, became the main aviation services' customer. The US POD found in this mode of transport a very suitable substitute to the traditional ones—sea and train—owing to its superior speed, a factor of paramount relevance for postal services, and in 1927, it established the first transcontinental air route linking San Francisco and New York.

However, the importance of the mail services would be brief as, throughout the remaining period between the world wars, the general-freight segment grew at a faster pace than the mail segment and would eventually outpace it. The segment that had driven aviation's evolution for the

first decades has been definitively relegated to an inferior position.

Growth Period: Mid-1940s to 1970s

Following the halt brought by World War II, civil aviation dived into a period of tight economic regulation. In 1944, the Chicago Convention (formally called the Convention Concerning International Aviation) was held with the purpose of defining an international regulatory framework for the future development of international civil aviation. However, the rift between participating countries was so deep that no overall agreement was achieved. On the one side, some countries, like the United States, sought a more liberal and open approach, on the other side, others—mostly European countries with their economies near ruin and with extensive wartime damage—preferred a close agreement where all economic and commercial matters would be under the supervision of one organization.

Even so, two main achievements were attained: first, several freedoms of the skies were mutually recognized, except in special circumstances such as war. These rights would later form the bases for future international bilateral agreements. Second, the International Civil Aviation Organization (ICAO) was established, under the auspices of the United Nations, with the clear mandate of developing the principles and techniques of international aviation and fostering the planning of international aviation.

In parallel, aviation companies recognized the need for an organization for discussion of aeronautical technical and operational issues that could defend their interests. The former International Air Traffic Association was relaunched and renamed under the designation: International Air Transport Association (IATA). ICAO and IATA are the two main bodies in civil aviation. They set most of the international standards, rules, and norms, as well as coordinate diverse business issues, such as rates and tariffs, schedules, or access to airports.

In the absence of a universal international law and in order to initiate international air services, each country was forced to engage in direct negotiations with every other country it wanted to fly into. These bilateral negotiations resulted, naturally, in a vast quantity of bilateral agreements. These agreements were normally conducted under

the auspices of IATA. The first bilateral agreement signed in 1946 was designated the Bermuda Agreement between the United Kingdom and the United States. The Bermuda Agreement served thereafter as a role model for other negotiations. The bilateral agreements impose rigid norms over several market issues (see Table 1).

In practical terms, bilateral agreements prevented competition among airlines, as capacity and fares were agreed and revenues were shared. After some years, a large number of bilateral agreements had been signed, ruling the international aviation sector. At the national level, the picture was not so different, with countries adopting either a public or a private, but heavily regulated, aviation sector. In any case, the aviation market was heavily regulated: fares, access, schedules, and routes were not defined by aviation companies but by public authorities. The outcome was an artificial market free of competition. Interestingly, these constraints did not hamper civil aviation's growth but the very opposite—the sector developed at a fast pace.

Throughout the 1940s, the civil aviation market gradually shifted its business focus toward the passenger segment. Several factors contributed to this change. First, the passenger segment became dominant in terms of revenues. Second, governments' attention turned toward this segment. Their

primary concern was assuring adequate aviation services to populations in order to promote the desired national equity and cohesion. Additionally, the growth of the passenger segment gave civil aviation a political role, as people complained and demanded further rights, whereas freight business has remained essentially within private scope that, naturally, does not complain. Finally, freight transport was in most cases already conveniently secured by surface communications, mainly rail transportation. Despite the growth of aviation, the volume of goods airborne was still modest.

In the 1950s, a second major technological breakthrough occurred in the aviation sector: the introduction of jet engines. These engines provided superior performance, in terms of both thrust and speed, compared to the former propeller engines, making possible the design of larger and faster aircraft. Larger aircraft meant more capacity (in terms of volume and weight) and faster aircraft meant longer routes and fewer stopovers.

The decades after World War II were very favorable for air cargo business, with rising demand for freight services sparked by robust economic development of the world's principal economic blocks, and cheap oil prices. Many companies that carried freight exclusively entered the field and became responsible for most of the market. This was particularly notable in the United States, and the success was such that in 1949 these operators carried 83 percent of the freight traffic and accounted for 73 percent of the revenues of the air cargo market.

Many passenger aviation companies (for example, American Airlines) also provided freight services. Freight was commonly carried on the lower deck of passenger aircraft, as technological development was rendering larger aircraft with enough space for passengers' baggage, mail, and other freight. Notwithstanding the growth of the freight sector, provision of freight transport services remained largely a side (or secondary) business meant for earning some extra revenues by filling available space.

The lesser relevance of freight business led companies to minimize the business's resources. In many of them, freight business consisted of selling, commonly through block space agreements (usually at a negotiated cost lower than the spot market but providing the carrier a fixed income), the available space on the aircraft's lower deck and, eventually, a

Table 1 Bilateral agreements

Issue	Common Features
Designation	Single designation
Routes	Point-to-point routes governmentally defined
Capacity	50 percent for each country
Fares	Decided at IATA tariff conferences
Ownership	Publicly owned Privately owned by national companies
Revenues	Obligatory 50:50 percent revenue pooling

Source: Reis, Vasco. "The Performance of the European Liberalisation Process—An Evaluation of the Scheduled Air Transportation Market." Master of Science Thesis, Oporto University, Portugal, 2005.

portion of the upper deck to third-party agents—freight forwarders—responsible for marketing, negotiating, and operating freight business. Consequently, over time, passenger companies would lose to freight forwarders most, if not all, contact with freight customers.

The dedicated freight companies' domain, however, faded out and by 1960 passenger companies controlled over 80 percent of international traffic and around 70 percent of the scheduled world freight traffic (with similar figures in the United States). Two main reasons may be pointed out: first was the lack of suitable aircraft for freight operations, as they were primarily tailored for passenger operations. Available aircraft lacked a reinforced fuselage and floor, ample doors, or internal arrangements for anchoring freight, which hindered freight-related operations.

Second, a more favorable business model for passenger airlines existed. Recall that passenger companies run two businesses in parallel: passenger and freight, and therefore they may allocate the flight's costs in their best interest. For example, passenger companies' freight rates can be lowered to cover only the increase in fuel consumption (marginal cost), while allocating all the other costs (such as aircraft acquisition and maintenance, crew or taxes) to passenger operations. On the other hand, freight companies run a single business, that is, freight operations. They have to allocate all the costs to this business. Inevitably, this results in higher freight rates.

It is worth mentioning that during this period a new breed of highly competitive companies—integrators—entered the market offering an innovative service: express freight services. Yet, it was not until the 1980s that they gained momentum.

Liberalization Period: Late 1970s to the Late 1990s

For more than 30 years, the civil aviation industry evolved within this environment. The outcome was a stagnant market, with many companies depending on subsidies in order to survive. The absence of competition, the inflexibility of rules, and the lack of stimulus led companies to reach a dead end, with enormous deficits and low efficiency. Other problems of regulation included restrictions on trade, distortion of the overall pattern of services, lack of incentives to modernization or improve, and no focus on the traveler. Carriers repeatedly reported

low load factors, and many were undercapitalized, inefficient, and unprofitable. As a consequence, fares were too high, as were labor costs. The oil crisis in the early 1970s further worsened the carriers' problems.

By that time in the United States, the civil aviation industry had reached an unsustainable situation, with government obliged to inject huge amounts of governmental subsidies in order to keep carriers operating. Furthermore, some voices, supported by several studies and reports that stated the problems and weaknesses of regulation, rose against the regulatory framework. There was an expectation that airline markets could be quite competitive and that even those with little competition should keep costs and prices down. The Civil Aeronautics Board conducted some research and found no advantages in regulation; consequently, it advocated deregulation. This situation evolved until October 24, 1978, when President Jimmy Carter signed the Airline Deregulation Act, which fully deregulated the U.S. domestic market.

After deregulation, the market underwent some distressing times, with many volatile entrants and with incumbents facing adaptation problems. Increased competition, a "boom" in air travel, and reduction of fares were other short-term effects of deregulation. New entrepreneurial carriers entered the scene, offering innovative products, such as frequent flyer programs and promotional fares. Incumbents followed their lead and also adopted a commercial-driven business attitude, becoming more competitive. However, after years of entries and exits, most of the new entries as well as some long-time carriers went into bankruptcy and an oligopolistic market again developed, with a diminution of real competition.

The star-shaped network, called as hub-and-spoke, became the common configuration for scheduled airlines, which reduced the number of direct flights. Furthermore, many routes disappeared because they were not profitable, which reduced the number of places served.

In terms of quality of service, an overall reduction of the quality of food, leg room, and in-flight service occurred. Moreover, overbooking and bumping of passengers became relatively frequent.

Despite the disturbing times and problems, in general terms, deregulation has been advantageous. After a decade of deregulation, fares fell by

about 7 percent on major routes, passenger boarding rose by 55 percent, scheduled-revenue passenger miles grew by over 60 percent, and employment increased by 32 percent. In 1977, 37 percent of passengers traveled using discounts; this increased to 91 percent in 1987.

After opening its internal market, the United States also engaged in relaxing the international one. Thus, in 1978, various liberal bilateral agreements were signed with European countries, namely, the Netherlands, Germany, and Belgium, and in the following two years with various Asian countries, including Thailand, Singapore, and Korea. Other countries have followed the United States example and deregulated their domestic markets. Canada, Australia, and New Zealand are some examples of countries that had already relaxed their national and international markets.

The pace toward liberalization of these markets was slower and less systematic than in domestic aviation, mainly due to opposition from some countries that refused to open their markets to competition. They feared that their companies would not withstand a competitive market and would lose some of the economic benefits of a regulated environment. Generally, the first move to liberalization has been relaxing the existing bilateral agreements through increased capacity limits, permitting more airlines onto routes, and increasing competition between airlines.

An interesting example exists in Australia where the government has granted the right (the sixth freedom of the skies) to some Asian companies (third-country carriers) to carry passengers from Australia to Europe via their hub, in order to increase competition and reduce tariffs. However, the move toward a global market has been painful and slow, the encouraging results and the increasing pressure from stakeholders have been pushing governments and regulatory boards to open their aviation markets.

The evolution of the European Union aviation industry was mirrored elsewhere, with countries regulating their own domestic aviation and creating bilateral agreements with other countries. These bilateral agreements that governed international aviation have evolved from the 1944 Chicago Convention. This framework developed until 1957, when the Rome Treaty was signed. The Rome Treaty represents the beginning of the European

community instituting the rules for a common market, and the Economic and Monetary Union. Moreover, the treaty envisaged free mobility for people, goods, services, and capital within the community, calling for the elimination of all protective barriers and obstacles. Under the treaty's philosophy, the existing system of aviation regulation was unsustainable, as the current system of airline regulation was anticompetitive and in opposition to the competitive spirit of the treaty; furthermore, market access or price-fixing restrictions worked against the freedom to supply services.

The European Commission was charged with the implementation of the Rome Treaty. However, at the outset, the mission was quite complicated as forces favored the existing regulatory system. Three main reasons can be pointed out. First, transports had a different position, under the treaty, than the other services. Title V (articles 71 and 80) relinquishes to the Council of the European Union the decision to rule and to legislate the Common Transport Policy. Second, air and maritime transport were not initially included in the Common Transport Policy (no. 1 of article 80). Third, countries and industry also favored the existing system and the status quo. These features reduced the European Commission's authority and, despite all initiatives, the market remained heavily regulated for several years. Changes arrived slowly and in different ways.

In the face of a continuous absence of more open European policies, some countries reformed their own domestic markets. The United Kingdom was the most active one and from 1984 until 1987 relaxed its bilateral agreements. Table 2 presents various liberal bilateral agreements features.

The first responses to liberalization were rather positive, with newcomers entering and incumbents responding accordingly. Furthermore, the European Commission and scholars presented several reports and studies that emphasized the inefficiencies of the European air market and benefits of a more competitive market. The small unit costs of the developed European charter industry and the United States' deregulation were also used as evidence of the potential benefits of liberalization.

The European Court of Justice also took an important role in changing European transport policy in 1974, with the *French Merchant Seamen* case declaring that rules governing competition in the

Rome Treaty applied to aviation, and in 1986, with the *Nouvelles Frontières* declaring that national rules should be in conformity with European laws. Its deliberations against the European Council and the existing regulatory system strengthened the voice of the European Commission. Finally, the European Council decided to introduce liberalization slowly and by phases. The underlying philosophy was to introduce evolution rather than revolution within the aviation market, as had happened within the U.S. domestic market in 1978. The Council determined that liberalization would take place in three steps. In each step, a set or “package” of legislative rules would be defined, aimed at the establishment of a free and competitive market akin to that within the United States.

The First Phase began in 1988, bringing timid winds of change, the Second Phase began in 1990, strengthening and spreading the competitive spirit; finally, the Third Phase began in 1993, establishing a competitive environment in the European market but only after a transition period until 1997. The European liberalization was one of a kind. Never in human history has such a large number of countries opened their domestic and international market to competition. Unlike the United States’ deregulation process, the European

Union’s aviation market did not undergo significant turmoil. Two main reasons may be pointed out: first, the process was incremental rather than sudden, leaving enough room for market agents to adapt, and second, the liberalization only affected the internal market of the European Union, but a significant part of the business came from non-European business that remained unchanged. The most notable consequence of the liberalization process was the rise of low-cost companies in the European Union.

The Twenty-First Century

The transition to the new millennium proved rather harsh for the aviation sector, as new dangers emerged in the landscape: economic turmoil, ever-increasing competitive forces from within and outside the aviation business, rocketing fuel prices coupled with an increasing awareness of sustainability, and quantum technological developments. Such forces began shaping the aviation business and leading many agents to find new ways of doing business.

The first decade of the 21st century will be recalled by the appearance of new forms of threats in aviation, namely, terrorism and diseases. The aviation sector has been for a long time a preferred

Table 2 Liberal bilateral agreements

Countries (Date)	Features
United Kingdom–Netherlands (1984)	Liberal route access and capacity with consultations Country of origin fares rules
United Kingdom–Luxemburg (1985)	Liberal route access and capacity Double disapproval on fares
United Kingdom–France (1985)	55:45 on capacity Liberal access No changes on fares
United Kingdom–Belgium (1985)	Liberal route access and capacity Double disapproval on fares
United Kingdom–Switzerland (1985)	Liberal route access and capacity Country of origin rules only for discount fares Minimum conditions for special fares
France–Federal Republic of Germany (1986)	Only greater freedom for route access

Source: Reis, Vasco. “The Performance of the European Liberalisation Process—An Evaluation of the Scheduled Air Transportation Market.” Master of Science Thesis, Oporto University, Portugal, 2005.

tool for terrorism acts. Common tactics have included bomb attacks or hijacking of aircraft. Yet, nothing was so devastating as the terrorist attacks of September 11, 2001, in the United States. The world woke up differently in the aftermath, and immediately governments all around the world imposed strict security and safety measures in the aviation production chain, particularly airports and air transport companies. Examples of safety and security measures include reinforcement of aircraft cockpits, universal baggage and freight screening, and thorough passenger screening procedures. The measures appear to be effective, since no other similar event has occurred. Nevertheless, the danger remains, as evidenced by the discovery in 2010 of small explosive devices in two cargo aircraft heading to the United States. In parallel, another very different but still dangerous threat emerged on the horizon, that of a new breed of contagious diseases, such as the severe acute respiratory syndrome (SARS) epidemic in Asia in 2002 and 2003, and influenza virus in Mexico in 2009. Aviation was unfortunately a victim of its own success. A threat that some decades ago would be easily contained within a specific region can now spread worldwide at unprecedented speed using the air transport networks.

Economic Turmoil

The world economy exhibits a cyclic nature, with periods of around 10 years. There were important economic downturns in 2001 and again in 2008, which is yet to be recovered from five years later. The state of the economy has a significant impact on the aviation sector. In periods of economic downturn, people fly less and less freight is shipped. Recent studies found that the air cargo business tends to grow between 1.5 to 2 percent above global gross domestic product (GDP), while others concluded that a correlation exists between airlines' net operating margin and the world's GDP. The aviation business was still recovering from the 2001 world economic recession when it was hit hard in 2008 with the subprime crisis in the United States and the subsequent economic crisis in the European Union and elsewhere. Caught in the middle of the economic turmoil, aviation agents could do little except survive and look for secure refuges. This has appeared in the form of either vertical, that is, between agents operating in different businesses

(for example, airlines and airports), or horizontal, that is, between agents operating in the same business (for example, airlines), agreements. Agreements bring synergies, generate opportunities for cutting costs, and ultimately lead to reduction in competition (that is, market concentration).

Agreements and Alliances

Agreements can include a wide set of forms and include multiple functions. The simplest types of agreements include only matters of a commercial nature and technical and operational aspects of the business. They entail low commitment and are often established on an ad hoc basis when necessary. At the other extreme, the most complex types of agreements entail long-run commitment and involve any sort of exchange of assets (including, but not limited to, terminal facilities, maintenance bases, aircraft, staff, traffic rights) or capital. Among these, the most developed refer to mergers and acquisitions between companies. However, governments seldom allow their national companies to merge or be acquired by foreign ones, for matters of sovereignty and economic protection.

As such, these types of agreements are usually limited to companies registered in the same country. In the United States, multiple mergers and acquisitions have recently occurred, for example, Continental Airlines merged with United Airlines in 2010, Delta Air Lines merged with Northwest Airlines in 2008, and American Airlines merged with US Airways in 2013. The most notable exceptions are in the European Union, owing to the European liberalization process and the implementation of the internal market. Multiple movements have also occurred. As an example, Lufthansa Airlines acquired a set of other airlines, including Brussels Airlines, Alitalia, Swiss International Air Lines, AG, and Austrian Airlines. Also, Air France merged with KLM, and British Airways merged with Iberia.

Airlines responded to the governmental restrictions on mergers and acquisitions through the establishment of alliances. The members of an alliance establish a set of commercial agreements among themselves, aiming to achieve the highest possible level of synergies within the freedom granted by the national governments. The benefits for the customers include a seamless travel experience in terms of level of service, tariffs, timetable, rights, or privileges.

There are currently three global alliances: Star Alliance, SkyTeam, and Oneworld. Available statistics for 2012 show that three of every four passengers were carried on one of these three global alliances. Each alliance includes a major airline from the United States (United Airlines in Star Alliance, Delta Air Lines in SkyTeam, and American Airlines in Oneworld), Europe (Lufthansa in Star Alliance, Air France in SkyTeam, and British Airways in Oneworld), and Asia (Singapore Airlines in Star Alliance, Korean Air in SkyTeam, and Cathay Pacific in Oneworld), in addition to multiple regional members. In 2012, Star Alliance was the largest global alliance with a total of 28 members and traffic of 650 million passengers.

Low-Cost Airlines

The low-cost airline (LCA) concept is arguably the most notable consequence of the deregulation and liberalization wave sweeping the air transport sector worldwide since the late 1970s. Over a period of three decades, the low-cost segment continued to grow, bringing significant changes to the air transport sector's status quo and impacting societies and economies (for example, through tourism and regional development or enhancement of populations' accessibility). Low-cost airlines, low-fare airlines, no-frills airlines, discount airlines, and budget airlines are just some of the terms commonly used to designate the new breed of air transport companies that emerged in the late 1970s in the United States after the air transport market's deregulation, in Europe in the late 1990s, and since then worldwide.

An LCA is an airline that offers very low fares and airport-to-airport services. In order to make a profit, LCAs follow very specific business models perfected to minimize costs and improve revenues. Differentiating features include direct sales of tickets, absence of frequent flyer programs, utilization of cheaper secondary airports, higher daily utilization of aircraft, paid in-flight services, paid checked luggage, and a higher density of seats.

Despite offering only direct connections and no amenities, the concept has proved very successful everywhere. Available statistics by OAG (formerly known as the Official Airline Guide) reported in 2012 a market share for LCAs of around 26 percent in terms of total seat capacity, which is a notable amount bearing in mind that

many countries remain regulated. In mature low-cost markets such as the European Union or the United States, the market share is stable at around 30 percent and 20 percent, respectively (in terms of total seat capacity). Despite the collective success of the LCAs' business model, available statistics show that airlines' actual rate of survivability is relatively low, with the majority going out of the market within five years of operations. What happens is a constant flow of new entries that is greater than the flow of companies that go out of the market. Indeed, sustainable profitability of an LCA business model is particularly difficult to achieve. Good examples are Southwest Airlines in the United States and Ryanair and Easyjet in Europe.

Other Modes of Transport

Competition comes not only from within the aviation sector. Increasingly, other modes of transport have been gaining a competitive edge. In the passenger market, the most notable competitor is the high-speed train (HST) or high-speed rail (HSR). Studies demonstrate that up to distances of around 310 miles (500 kilometers), HSTs can be as much, if not more, competitive than air transport. The main competitive advantages are the following:

- HSR stations are typically located in city centers, while most airports are in the outskirts, leading to longer access times.
- HSR have less stringent safety procedures, leading to faster and more comfortable security screening procedures.
- HSR services tend to have higher frequencies, which lead to better quality of services and shorter waiting times.
- HSR prices are often in line with airfares.

Beyond 310 miles, the higher speed of aircraft prevails over the other factors.

A similar trend is also visible in the freight market. Recent years have seen a progressive incursion of road and sea modes into markets traditionally captive of air transport. Although being by far the fastest mode of transport and highly reliable, air transport is also the most expensive. A rule of thumb is that an air consignment is 10 times more expensive than a sea consignment. Such difference is enough to make customers carefully reflect on the importance of time

for their goods, particularly in times of economic recession. In parallel, sea, road, and rail transport agents have been increasing their levels of reliability and, supported by technological developments, reducing transit times. The same trends have not been matched by air transport companies, resulting in a progressive shrinkage (and eventual overcoming) of the competitive position of air cargo services. Also, consumer markers have been changing. The rate of creation of high-value and new mass market products is decreasing, and those existent are maturing toward commodities. As these industries mature, shipping time has become a less critical factor.

Fuel Prices and Sustainability

Airlines' fuel costs represent around 25 percent of an airline's cost structure (market average values). Therefore, variations in fuel prices have an important impact on airlines' profitability. Fuel price is related to oil prices, and oil is very much a commodity. The price freely fluctuates on the market in relation to its availability and as influenced by speculation. Although airlines can protect themselves against sudden market fluctuations by hedging future fuel purchases, nothing can be done against a sustained upward trend in fuel prices.

As recently as 2008, oil prices rocketed to unprecedented values, rising above the threshold of US\$140 per barrel (compared with US\$60 in mid-2007). This evolution hit the aviation sector so hard that most companies decided to introduce fuel surcharges. By mid-2008, oil prices start reducing again until reaching normal prices by the end of that year. Instability in oil prices started in the 1970s and there are no reasons for slowing down as the finite sources of oil are being exhausted at a fast pace. Airlines are under increasing pressure to reduce fuel consumption and to find suitable alternative fuel sources.

Aviation is an intensive energy-consumption industry. Around 100 percent of energy is derived from oil, a fossil fuel. European Union data on emissions show that the aviation sector accounts for 3 percent of total European Union greenhouse emissions (2010) and forecasts made available by the European Commission predict that, at current trends, aviation emissions are likely to double from present levels in 10 years. The aviation sector's carbon footprint cannot be neglected and agents are responding accordingly. A recent

survey found out that most airlines are aware of their carbon footprint, make that information available, and some define targets for reduction of greenhouse gases.

As an example, Air France reduced fuel consumption and carbon dioxide emissions by 12 percent between 2000 and 2006, and the U.S. airlines collectively reduced carbon dioxide emissions by 3.7 percent from 2000 to 2006. Initiatives for reducing the carbon footprint include acquisition of state-of-the-art aircraft, adoption of more fuel-efficient climb and landing approaches, and reduction of aircraft taxiing and waiting times. A recent statement by the airlines' representative association, the International Air Transport Association, referred to the strategic goal of achieving a neutral carbon footprint by 2050. Such an objective will require the development of new technology, because current jet engines are not emission free. Meanwhile, a growing number of airlines are implementing carbon offsetting mechanisms. The purpose is to compensate for the emissions by either promoting reductions in other sectors or supporting reforestation projects.

Looking to the air transport value chain, airlines are arguably the agents with minor influence in the aviation sector's carbon footprint. As they are technology users and not technology developers, they can only use what is available in the market. They have to navigate across suboptimal airspaces, designed by other agents. A growing number of airports are congested, leading to delays and other fuel-inefficient operations (studies demonstrate that aircraft in holding patterns waiting authorization to land have an increase of around 30 percent in fuel consumption, compared to consumption at cruise speed).

Technological Developments

Aviation is the consequence of technological development. Over time, the sector has been a testing ground for innovative solutions and constantly incorporating innovative solutions. Throughout its short period of life, the sector has undergone numerous technological leaps, for example, radar in the 1930s, jet engines in the 1950s, wide-body aircraft in the 1970s, and computer reservation programs for selling passenger tickets in the 1980s.

Recent decades have been characterized by major achievements in every scientific domain, which

have been transferred to the civil aviation industry, for example, composite materials for construction of lighter aircraft, biofuels for reducing dependency on fossil-based fuels, and satellite-based air traffic control. The B787 aircraft by Boeing is mostly made of composite materials, leading to substantial gains in fuel efficiency and comfort. Also, the Airbus flagship aircraft, the A380, can carry up to 900 passengers.

Another fundamental technological evolution is the Internet. The Internet rapidly became the preferred communication and distribution channel for advertising and selling tickets, enabling the development of new marketing and business strategies. The success of the LCAs is largely supported by the Internet and the possibility of selling tickets directly to passengers without the need of a travel agent.

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See Also: Aeronautics; Air Cargo Carriers; Air Passenger Carriers; Air Travel; Aircraft Design; Aircraft Propulsion, New Technologies of; Airline Deregulation Act of 1978; Airline Flight Reservation and Ticketing Systems; Airline Marketing; Airline Passengers; Aviation, Commercial/Business; Biofuels; Emissions Trading Schemes; International Air Passenger Transport.

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Airline Marketing

Airlines are companies that transport people and cargo to different locations around the world. They do so using a variety of aircraft, which are large and expensive pieces of equipment requiring very high levels of safety and maintenance. Hence, ownership of a fleet of aircraft represents an important barrier to entry for would-be competitors, and there are comparatively few rivals in any particular sector. This was particularly true in the early years of the industry, when many markets were restricted to national or regional carriers, many of whom received state subsidies in one form or another.

The industry began to be transformed in 1976 when the U.S. government commenced a program of deregulation and the move toward "open skies" or "blue skies" agreements, which opened markets to a much greater degree than before. In the years since, new agreements have revealed the lack of competitiveness of some airlines and high-profile bankruptcies (for example, American Airlines, Delta Air Lines, and Northwest Airlines) and the struggles of some national carriers in Europe and elsewhere. New entrants have emerged, of course, and among these, low-cost or budget carriers have become prominent. Following the model of Southwest Airlines, budget carriers have stripped down the components of services customarily expected as part of a flight experience in order to reduce costs and airfares.

Since flying has become a mass market as tourism has blossomed around the world, new customers who would not previously have been able to afford air travel are entering the market, and their expectations of service are not always as high. These are among the factors most influential in shaping the marketing strategies of airlines.

Branding and Loyalty

In order to make airline routing more efficient and to extend the network of individual companies, many routes now share codes. In other words, two or more airlines share a particular route or flight, which is marketed in the names of all partners. This can be problematic in that passengers may be unwilling to disentangle which part of the service is the responsibility of which agency in the event of any problems. One bad customer experience—on the basis that bad news always travels much quicker and farther than good news—can damage the reputation of a number of companies that have only limited ability to control what has occurred. However, this is part of a larger problem affecting airlines, which is their lack of control over so many of the important service encounters that do so much to influence customer satisfaction overall. For example, baggage handling, excessive and intrusive safety screening techniques introduced in the wake of actual and attempted terrorist attacks, and the quality of catering in the airport might all be conflated in the mind of the customer with the responsibilities of the airline from which tickets have been purchased.

It is a somewhat contradictory phenomenon in marketing that the more effort that is expended in promoting the branding of a service, the greater the risk of loss of brand value from third-party activities. Airlines are generally not in the position of being able to conduct vertical integration to take over groundside services; indeed, the opposite approach is much more common as different components are spun off to third parties contracting through market transactions.

Despite these issues, airlines have used brand loyalty as a primary means of connecting with customers. Air miles schemes offer reduced-cost or free tickets to frequent travelers. These are particularly valuable to large-scale corporate customers who have regular schedules to fulfill and who might also value the partnerships with car rental or accommodation providers that are often included

within packages. Internationally, there is a trend for loyalty card schemes of this sort to broaden their coverage to more partners and deepen their coverage to more goods and services.

One mode of attracting customer attention in the past was the use of young women as stewardesses on airplanes. More or less blatantly, airlines hired only attractive and young women with a minimum height regulation (based on safety regulations) and promoted their lines through the bodies of the stewardesses and their compliance to customer wishes. The job still appears a glamorous one in many parts of the world. However, greater awareness of gender and workplace relations in airlines in the developed world has required more diversity in this occupation, and the nature of advertising has also moved from explicit sex appeal to such factors as comfort, luxury, and reliability.

Segmentation

One of the most important marketing techniques for airlines is segmentation, which means dividing the overall market (that is, everyone who flies or might fly) into smaller groups of people who are relatively homogeneous in terms of how they use a service. With this information, companies can identify which segments to address for any particular product as well as the best ways of marketing to them.

Segmentation on airplanes is very evident in the presence of economy, business, and premium classes of travel, which are physically separated from each other and with unmistakable evidence of deferential treatment available for different prices. However, there are more subtle ways in which this has been approached. The destination involved might provide a clue for how potential individual or group travelers might be approached, for example, in the case of Muslim travelers wishing to go to Mecca for the hajj or sports fans wishing to travel for a specific sporting occasion. People traveling for holidays might be willing to accept lower cost options at unpopular times of day, while business travelers might be willing to pay a premium (or have their companies pay it) to arrive and depart at more convenient times. The differing motives of people are likely to be seasonal in nature and will also change in time alongside changes in the external environment more generally, as some destinations gain popularity and others lose it.

Cost Leadership

The emergence of budget carriers with much greater latitude to establish their own networks under deregulated, open skies conditions has seen the rise to prominence of cost leadership as a dominant marketing strategy in the 21st century. Companies in this sector recognized the increasing number of people able and willing to fly either for the first time or on a more regular basis if low-cost flights were made available to them. To reduce costs, budget carriers stopped offering free in-flight entertainment and meals, charged passengers extra for checking luggage, and sweated the aircraft assets by increasing the average daily amount of flying time from around six-to-eight hours to as much as twice that. Rapid turnaround times and avoiding the use of land bridges are other operational approaches to lowering costs, and the application of science has also been used through research into paint technology so as to save some money by using lighter coatings.

These flights have certainly been very popular and have helped create new sectors of the market; for example, flights from the United Kingdom to low-cost Baltic destinations have become popular for the stag weekends that groups of young (usually) men take before one of them marries. However, there has been some contestation of the practices in terms of the quality of service, notably, the distance from the supposed destination that the alternative airport might actually be and the impact on destinations that the new trade has caused. It is also the case that aircraft flights are very damaging to the environment in terms of both emissions and the physical impact on land cover caused by the transportation infrastructure required. There is, consequently, a tension between the desire for people to join in the international tourism industry and the long-term societal need for reduction in burning carbon-rich materials.

Competition

The September 11, 2001, terrorist attacks in the United States led to the grounding of aircraft in many parts of the world and, as a minor consequence, led people to reevaluate their need to be physically present in a specific location to conduct business negotiations. Video conferencing technology, combined with breakthroughs in the Internet and mobile telecommunications, has come to represent a significantly important alternative to regular air travel. Further, increasing awareness of

the environmental damage caused by air travel and the importance of local productions also represent forms of competition to airlines, which have yet to formulate new marketing strategies in response other than to seek out new market sectors.

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See Also: Air Travel; Airline Industry; Aviation, Commercial/Business; Economics of Air Travel.

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Airline Passengers

America's first commercial airline flight took place in 1914, and passenger airline services on a regional basis began to develop in the mid-1920s. In 1929, 173,405 Americans took advantage of the growing services, most of them businessmen at the upper level. After 1945, the airlines began to compete with bus and rail services for passengers, and by the end of the 20th century, 50 percent of Americans were taking at least one round-trip flight a year.

Passengers require reservation and record management. For much of the history of commercial flight, such records were kept manually using record books, reservation cards, and other printed media, but a computerized system was introduced in the 1960s. In the 21st century, information is maintained by a network of computer reservations systems accessible by multiple airlines and travel agents, and paper tickets, in use since the first passenger flights, have yielded to electronic tickets.

In 1926, the first year the U.S. government compiled data on the airline industry, 6,000 passengers flew 1 million passenger miles at a cost of \$1.59 per mile (adjusted for inflation). In 2012, more than

8 million passengers flew over a billion passenger miles at a cost of 11.3 cents per mile. Yet many of those millions in 2012 were unhappy passengers. They filed 11,445 complaints with the U.S. Department of Transportation in 2012, an increase of more than one-fifth from the previous year. The rate of complaints per 100,000 passengers also rose, from 1.19 in 2011 to 1.43 in 2012.

This season of passenger discontent comes after the U.S. Department of Transportation implemented new passenger protections in 2009 and 2011. The changes in 2009 dealt with lengthy delays after passengers were on the plane. The regulations prohibited U.S. airlines operating domestic flights from permitting an aircraft to remain on the tarmac for more than three hours without deplaning passengers. Exceptions are permitted for safety or security. The airlines are also required to provide passengers with food and potable drinking water within two hours of delays and to provide access to lavatories and medical attention, if needed.

The first airline consumer protection rule brought significant improvement in the airlines' record of delays, with the largest U.S. airlines reporting only 16 tarmac delays of more than three hours during the first 10 months the regulations were in effect, compared to 664 extended delays during the previous 10 months. The regulations implemented in 2011 expanded the ban on tarmac delays, required reimbursement for lost baggage, increased compensation for customers involuntarily bumped from flights, and mandated disclosure of hidden fees. Despite these changes, shrinking seat size and overbooked flights ensure disgruntled passengers.

Reservations

As air travel became a favored mode of transportation for more people, reservation systems became essential. Early systems utilized cards organized by departure date and stored in tubs that moved from one reservation agent to another as needed. These manually processed reservations could be made only 30 days in advance of departure, and each airline maintained its own system. A single reservation transaction could take as long as two hours, and even when efficiency improved, the average transaction consumed 45 minutes. This procedure continued largely unchanged until the Semi-Automated Business Research Environment (SABRE) revolutionized the reservation system in the 1960s.

SABRE was proprietary to American Airlines, but other airlines soon launched their own computerized systems. Delta introduced DATAS (Delta Automated Travel Account System) in 1968, and United followed with its Apollo system in 1971. The proprietary systems began granting access to travel agents and after deregulation evolved into multi-airline distribution systems, or global distribution systems (GDSs), which functioned independently of airlines. Most reservations made through a travel agent, whether in physical travel agencies or online, go through a GDS. Airlines now pay the GDS a fee of around \$12 for each round trip booked, fees that total \$7 billion a year. The efforts of airlines to avoid these fees by having passengers make reservations directly through the airlines have met with limited success. If the common technical standard for direct-connect services proposed by the International Air Transport Association (IATA) in November 2012 is adopted, travel agents and passengers may bypass the GDS and make reservations directly through the Web sites of airlines.

Tickets

Airline tickets were introduced in 1909 with the earliest passenger flights. For most of the history of passenger flight, "ticket" referred to a paper confirmation that a person had purchased a seat on a flight on an aircraft. Depending upon the source, the first electronic ticket for airline passengers was offered by Atlanta-based, low-cost ValuJet in 1993 or by Southwest Airlines in 1994. By the end of the decade, more than half of all airline tickets were paperless. Before 2008, the year set by IATA for a full transition to e-tickets worldwide, 97 percent of tickets sold in the United States were electronic.

E-tickets have distinct advantages for passengers and for airlines. They cannot be lost since they exist in a computer database network and can be easily replaced if a printout is misplaced, and they are more difficult to steal since only a person with the proper identification can use the ticket. Paper tickets are more complicated to replace, and replacement sometimes requires additional charges. E-tickets make it easier for airlines to contact customers about changes or cancellations and to process refunds more quickly.

Full conversion to e-tickets would save airlines an estimated \$3 billion annually. Using e-tickets is also environmentally responsible because,

according to an IATA estimate, if e-tickets were used exclusively, the industry would save the equivalent of 50,000 mature trees each year, about 3 square miles of forest.

E-tickets are saving time, labor, traveler frustration, and trees, but they are not saving money for passengers. In 2011, domestic fares rose by an average of 8.3 percent over the previous year and increased another 3.1 percent in the first nine months of 2012, according to the U.S. Department of Transportation's Bureau of Transportation Statistics. Still, more passengers buy tickets. The Bureau of Transportation Statistics reported that 815.3 million scheduled passengers traveled on U.S. airlines and on foreign airlines serving the United States in 2012, a 1.3 percent increase from 2011.

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See Also: Air Passenger Carriers; Airline Flight Reservation and Ticketing Systems; Airline Flight Scheduling; Airline Industry; Airline Marketing; International Air Passenger Transport.

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negotiated a government contract to deliver mail, establishing a pattern of cooperation between government and the airlines. Labor unions were virtually nonexistent in those early years, consisting only of the Airline Pilots Association (ALPA). As the industry expanded to meet increased commercial demands, labor issues increasingly demanded attention. Until the late 1950s, U.S. government officials left most labor issues to airline industry officials. Collective bargaining issues were regulated by a 1936 extension to the Railway Labor Act of 1926. As a result, the Civil Aeronautics Board (CAB) was allowed to set airline fares and establish the routes that each airline could fly. Because of stipulations in the original act, negotiating contracts could be a lengthy process. Throughout contemporary history, labor problems in the airline industry have been heightened by deregulation, bankruptcies, mergers, and widespread economic downturns.

An Evolving Industry

In 1958, the payroll for the airline industry was \$800 million, comprising 41 percent of total industry expenses. During that year, there were 15 strikes that lasted from one half day at Eastern to 108 days at Western. The main contentions involved higher wages for pilots and crews, job security, and jurisdictional disputes between pilots and flight engineers. As tensions heightened, President Dwight D. Eisenhower established Emergency Board Number 123 to serve as mediator. By the end of the decade, the number of unions had grown to 31, representing some 49,000 employees. The three largest unions were the International Association of Machinists with 27,913 members, the Transport Workers Union with 15,354 members, and the Airline Pilots Association with 14,354 members.

The Airline Stewardesses Association, the first flight attendants' union, was established in 1945 by stewardesses at United Airlines. The following year, the Airline Stewards and Stewardesses Association was established as a rival union under the auspices of the Airline Pilots Association. Early concerns focused on increasing wages, improving working conditions, and winning the right to redress grievances. The two unions merged in 1949, but women were often unhappy with the male-dominated leadership, and infighting was common. Beginning

Airline Pilots and Crews, Labor Issues of

Aircraft came into their own during World War I, and commercial airlines began establishing themselves in the years after the war. In 1926, Colonel Lewis Brittin founded Northwest Airlines and



Flight attendants on a Russian Aeroflot Sukhoi Superjet 100 aircraft in November 2011 point out the emergency exits to passengers during their onboard safety demonstration.

in the 1960s, the women's movement had a major impact on how flight attendants dealt with labor concerns as they battled against weight, marriage, maternity, and age restrictions. By 1974, the union had become the Association of Flight Attendants, an autonomous affiliate of the ALPA.

Deregulation and Bankruptcies

Within the airline industry, the major event of the 1970s was deregulation. Passed by Congress in 1978 and signed into law by President Jimmy Carter, passage of the Airline Deregulation Act meant that the industry no longer had to seek government approval to add or withdraw domestic routes. Consequently, competition among the airlines increased significantly. In 1977, President Carter appointed Alfred Kahn as head of the CAB, and Kahn launched a campaign to deregulate the industry. Kahn gained support by demonstrating that unregulated flights inside each state were cheaper proportionally than interstate flights that were the subject of federal regulation. Deregulation and greater competition did result in reduced fares for customers, but they

also led to lower wages and declining working conditions for airline industry employees.

One of the major labor issues of the 1980s involved the number of pilots required to fly jetliners such as the Boeing 737 twinjet and the McDonnell Douglas DC-9 Super 80: the pilot's union insisted that safety called for three pilots, but management and the Federal Aviation Administration (FAA) insisted that only two pilots were needed. A presidential task force ultimately upheld the FAA's decision, agreeing that the use of two rather than three pilots did not impair safety.

In the 1990s, Northwest, the oldest American airline still in operation, began to be known as "North-worst" because of its record of poor customer service and delays in flights. Pilots at the airline expressed dissatisfaction with issues related to wages, job security, retirement benefits, per diem allowances, and profit sharing. As a result, tensions continued to mount. In 1993, the American Airlines flight attendants union chose to strike during the Thanksgiving season, leaving scores of travelers stranded. When the Allied Pilots Association initiated a strike in February 1997, President Bill Clinton responded by instituting the mandated 60-day cooling-off period allowed by the Railway Labor Act of 1926, which forced strikers to return to their jobs while negotiations were under way.

In a December 1, 2011, article written for *Slate*, Matthew Yglesias reported that throughout its history, American passenger aviation had generated cumulative earnings of negative \$33 billion. Between 1990 and 2011, the airline industry filed 189 bankruptcy petitions. Most of those filings were the result of major disputes with labor unions.

Twenty-First-Century Issues

In the early years of the 21st century, airline labor problems continued to mount, involving pilots, flight attendants, ground crews, and other employees involved in negotiating new contracts. Because a number of airlines had been pushed to the brink of collapse, many employees had not had a raise since the turn of the century. Problems grew so intense in the summer of 2012 that journalists dubbed it "the summer of discontent." Employees at United, which had merged with Continental, were unsettled because of the failure to reach agreements with its major labor groups, and employees at Continental were waging

protests and discussing a possible strike. Southwest announced plans to begin outsourcing jobs to temporary workers. The Association of Professional Flight Attendants expressed general dissatisfaction with current working conditions.

Economic problems have frequently been accelerated by labor and mechanical problems, particularly in the case of airlines struggling to stay afloat. In September 2012, flight delays and cancellations resulted in a 4 percent loss for bankrupt American Airlines. That loss led to a 6 percent cut in domestic flights. Other airlines also continued to lose a portion of their customer base: Delta's passenger count fell by 1.9 percent, United's by 2 percent, and Southwest's by 2.6 percent during that same month.

As 2012 drew to a close, United and its pilots finally signed a contract after two years of labor tensions. However, tensions with maintenance crews continued. In November, United suspended a pilot who had delayed a flight by insisting on changing a slashed tire due to safety concerns. United blamed maintenance labor problems for the vast majority of delayed and scrubbed flights. United's flight attendants also continued to press for a wage increase.

For most airlines, keeping labor costs manageable is essential to remaining in business. Labor issues frequently inconvenience customers, but maintaining safety and customer satisfaction must necessarily remain top priorities for both employees and management.

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See Also: Air Passenger Carriers; Airline Deregulation Act of 1978; Airline Industry; Aviation, Commercial/Business; Economics of Air Travel.

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Airline Service Quality Modeling

Quality of service index (QSI) models are used to estimate market shares and passenger volumes. QSI models were developed by the U.S. government in 1957 and were used during the regulation era to evaluate carriers' requests to increase fares on specific routes. The first QSI models allocated demand across different routes as a function of three service quality attributes: aircraft equipment type, number of stops, and flight frequency.

After airline deregulation in 1978, the definition of service quality was expanded to include other attributes, such as the departure and/or arrival times, departure day of week, connection times, code shares, average fares, and carrier (or brand) preference. The inclusion of these attributes enables carriers and route analysts to examine the following types of questions: How do mergers and acquisitions impact carriers' profitability and average fares paid by consumers? How does the presence of one or more low-cost carriers on a route impact passenger volumes, revenues, and profitability? Which flights should be marketed as code-share flights in order to maximize revenue? Which routes become

unprofitable to serve when fuel costs increase? How will reducing connection times increase passenger volumes and revenues? How will introducing a new aircraft that can travel farther or fly faster benefit airlines and consumers? How many and what types of aircraft should a carrier purchase? Should a carrier increase service at an existing hub? Should a carrier add flights to an existing market? Should a carrier introduce new nonstop service in a market?

Estimation of QSI Models

QSI models predict the impact of service level changes by calculating an index for each itinerary on a route. The QSI index for an itinerary is given as the product of coefficients (β) and itinerary attributes. The coefficients provide information on how customers value schedule attributes. For example, a large negative coefficient associated with connection time indicates that passengers prefer shorter connections and are willing to pay more to avoid long connections.

QSI coefficients are obtained using data sets that provide information about the schedules offered and which itineraries passengers purchased. Schedule information is typically easy to obtain and accurate. In contrast, passenger information is often difficult (or impossible) to obtain and may be incomplete and/or biased. Although carriers collect detailed information about their own customers' purchases, they have limited information about their competitors' customers. Historically, information about competitors' customers was obtained from commercially available passenger databases compiled by computerized reservation systems (or CRSs).

In the past, CRS data provided useful market share information because the majority of customers made their airline reservations by calling travel agents, who used the CRSs. However, Internet bookings and carrier-direct bookings (such as those made via the airline's phone reservation system) are not captured in this database, and the reliability and usefulness of this data set has deteriorated. Today, the CRS data is highly biased toward business travelers, who have different price sensitivities and schedule preferences from leisure travelers.

Within the United States, carriers have been able to use alternative databases to estimate QSI coefficients. These databases, which are commonly referred to as the DB1A and DB1B data sets, refer to the Origin and Destination Data Bank 1A or Data

Bank 1B databases that are maintained by the U.S. Department of Transportation. These databases are based on a 10 percent sample of flown tickets collected from passengers as they board an aircraft operated by U.S. airlines. The CRS database, as well as the DB1A and the DB1B databases, contain average monthly or quarterly price information. The lack of detailed pricing information limits the ability to use QSI models to understand the impact of prices on customer choices. For these reasons, there has been increasing interest in exploring alternative data sources for estimating the coefficients of QSI models, particularly among non-U.S. carriers.

Alternatives to QSI Models

Other models, namely those based on discrete choice models, have also been used to allocate demand across itineraries. Discrete choice models are conceptually appealing because they can incorporate different competition patterns among itineraries. For example, a discrete choice model is able to incorporate increased competition among itineraries that depart at similar times of the day. Thus, if a carrier introduces a new nonstop flight at 8 A.M., a discrete choice model would predict that this new itinerary would draw more passengers from nonstop flights departing in the morning than from nonstop flights departing in the evening.

A major U.S. airline published a study that compared demand forecasts produced from QSI and discrete choice models. This study found that the discrete choice model forecasts were consistently superior to those of the QSI model, with the magnitude of errors reduced on the order of 10 to 15 percent. In practice, however, the QSI model is often preferred over the discrete choice model due to its perceived ease of implementation.

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See Also: Air Travel; Airline Fares; Airline Flight Scheduling; Airline Industry; Airline Marketing; Economics of Air Travel; Travel Modeling.

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Airplane Disasters

Since the advent of powered flight, airplane accidents and incidents have been part of civil aviation. Accidents, in fact, are expected, given that manned flight is dependent on man-made equipment operated by humans. The room for error and malfunction is great. Air enthusiasts quickly point out that, statistically, air travel is safer than automobile travel. A U.S. Department of Transportation statistical comparison of accidental deaths between 1999 and 2003 reports an average of 138 air accident deaths per year, compared to 36,676 motor vehicle deaths. Those numbers make the odds of dying in an air accident 1 out of 2.067 million, compared to 1 out of 7,700 for automobile deaths. Nevertheless, the dramatic nature of air accidents, the ability of 21st-century digital media to capture images of catastrophic accidents, and the fact that air accidents can kill hundreds of people in one incident make them especially frightening to the public. The following is a look at some of the deadliest or most notable and influential air accidents.

The First Air Fatality

Even people with little knowledge of aviation history know that Wilbur and Orville Wright, two American bicycle repairmen, inventors, and entrepreneurs, invented the first successful powered aircraft. Their first flight came in 1903 at Kitty Hawk in the Kill Devil Hills along the beaches of North Carolina. People may not know, however, that Orville Wright was also involved in the first fatal air accident.

The Wright brothers spent much of their time after perfecting the Wright Flyer trying to sell it to the U.S. Army. The Army would not consider a contract for airplanes unless the Wrights could prove their flyers could carry more than one passenger. At Fort Myer, Virginia, in 1908, the Wrights began a series of demonstrations to prove just that. Orville successfully flew Lieutenant Frank Lahm on September 10, then Major George Squier on September 12. On September 17, Lieutenant Thomas Selfridge, a member of the Army board assessing the aircraft, went up with Orville. During the flight, however, one of the Flyer's two propellers fell away. The plane was essentially a powered version of the cloth and wood gliders the Wrights had flown at the start of their experimental flights, and Orville tried to glide the crippled craft down.

The plane's weight characteristics, with a faltering engine and a passenger, were different from a glider's, however, and Orville could not get it under control. It crashed nearly nose first into the ground before a crowd of 2,000 people. Both Orville Wright and Lieutenant Selfridge were trapped under the wreckage of the flyer. Spectators pulled both men alive from the crash, but Selfridge died later that day of a skull fracture. Wright suffered leg, hip, and rib fractures. Selfridge, the first fatality of the aviation era, is buried in Arlington National Cemetery outside Washington, D.C.

First Commercial Air Accidents

The first commercial air accidents occurred soon after the end of World War I. The war had served as a school for many pilots who sought to make a living from the skill in peacetime. On August 2, 1919, two former Italian military pilots took off from Venice, Italy, in a Caproni Ca. 48, a tri-wing wartime bomber converted to carry passengers. Records are inconsistent, but from 12 to 15 passengers were aboard. At about 3,000 feet, the plane's ungainly wings buckled and collapsed. Some of the passengers tried to



U.S. National Transportation Safety Board investigators walk toward the charred fuselage of Asiana Airlines Flight 214 in San Francisco, California, the day after it crashed on landing after a flight from Incheon, South Korea, on July 6, 2013. The crash led to the deaths of three passengers and 181 injuries. As with many crashes, the aftermath drew attention to potential improvements to be made to safety features, as two evacuation slides deployed inside the aircraft and temporarily trapped flight attendants within.

escape by jumping from the passenger compartment, but everyone died in the crash.

Four people died in December 1920 when an aircraft crashed on takeoff at a London airfield. No air deaths were recorded in 1921, making that the last year in which no air fatalities occurred.

The next year, 1922, saw the first mid-air collision of two airliners. The pilots of a de Havilland DH.18A and a Farman F.60 Goliath were flying in bad weather, and both were using roads on the ground near Picardie, France, as navigational aids. Everyone on both planes, seven people in all, died in the crash. The crash prompted the codification of distinct air routes in Europe, the installation of radios in air transports, and the rule that pilots must stay to the right when encountering other aircraft.

Single Worst Air Disaster

History's single worst air disaster occurred March 27, 1977, at Los Rodeos Airport on Tenerife Island in the Canary Islands. The accident was the culmination of many disruptive events.

Two passenger aircraft, a Dutch KLM 747 and an American Pan Am 747 were among many diverted that day from nearby Gran Canaria Island airport, where a separatist (who wanted Canary independence from Spain) had set off a bomb earlier that Sunday. As the planes waited for clearance to leave Tenerife, the weather changed, and a dense fog covered the airfield.

Shortly after 1 P.M. the planes received permission from air traffic controllers to begin taxiing into takeoff positions. Air controllers, however, had no ground radar, and the fog limited their vision as well as that of the pilots on the jets. Recordings of radio traffic between the planes and the tower revealed confusion in the conversation between all the people involved. In the confusion, both 747s wound up heading toward each other on the same runway. The Pan Am craft was taxiing, but the KLM plane was gathering speed for takeoff.

The Pan Am crew saw the KLM plane's landing lights pierce the fog, then realized the plane was barreling down on them at nearly 160 miles per

hour. The Pan Am's pilot tried to make a left turn off the runway and onto the grass. Amid a flurry of cursing on the radio, the KLM crew rolled back their controls and tried to take off over the Pan Am plane. The KLM pilot threw his plane into such a steep attitude that its tail threw sparks as it dragged the runway.

The maneuver was not enough. The KLM's landing gear struck the upper starboard side of the Pan Am plane and its two right-side engines tore through its fuselage. Then it climbed about 100 feet before it crashed. The KLM's full fuel tanks ruptured and exploded. All 248 people on the KLM flight died. On the Pan Am aircraft, 335 people died, but 61 survived.

The disaster prompted a review of international airport procedures. The review immediately mandated uniform language between aircraft and air traffic controllers, as well as the practice of aircraft crew members repeating critical portions of controllers' instructions.

The 1977 crash was not the only major accident at Tenerife. A few years earlier, on December 3, 1972, a Convair CV-990 operated by Span-tax climbed about 300 feet off the runway, lost control, and crashed, killing 155 people. Like the KLM–Pan Am crash in 1977, the Convair accident occurred in low visibility.

On April 25, 1980, yet another plane went down near Tenerife killing all aboard. The plane, a Boeing 727 operated by Dan-Air, was in a circular holding pattern above high ground near the airport. The crew, however, had not reported their position, and they were too low to safely navigate the mountainous area. The plane crashed into Mt. La Esperanza, and 146 people died.

Grand Canyon Disaster

On June 30, 1956, a Trans World Airlines (TWA) Lockheed Constellation and a United Airlines DC-7—both four-engine, propeller-driven aircraft (the Constellation with a distinctive tri-rudder design)—left Los Angeles International Airport within three minutes of each other: TWA Flight 2 bound for Kansas City, and United Flight 718 for Chicago. The TWA plane flew at 19,000 feet, and the United aircraft was 2,000 feet above it at 21,000 feet.

As both aircraft neared the Grand Canyon, they flew into rough weather and clouds. The captain of TWA 2 requested permission to climb to 21,000 feet,

but air traffic controllers denied the request, given that United 718 was at the same altitude. The TWA captain then asked to get 1,000 feet above the clouds and go on visual flight rules (VFR). Air traffic control assumed that both aircraft would then be able to see each other. Incredibly, with both planes on VFR, air controllers had no further responsibility to watch the craft. At about 10:30 A.M., the planes collided over the Grand Canyon. The United DC-7 hit the TWA Constellation's tail, and DC-7's propellers ripped open the Constellation's body. The Constellation's tail severed and began to fall; the front of the plane dived nose first into the canyon. The United flight also plummeted, hitting the top of a nearby mesa; 128 people died.

The Grand Canyon disaster prompted a massive \$250 million overhaul of the nation's air traffic control system. The federal government also responded with the creation of the Federal Aviation Administration (FAA).

Japan Airlines Flight 123

On August 12, 1985, Japan Airlines (JAL) Flight 123 suffered an explosive decompression 12 minutes after takeoff from Tokyo International Airport when the fuselage of the 747 ruptured near the tail. The explosion severed electrical and hydraulic lines, rendering the plane uncontrollable. Pilots attempted to steer the jet toward a safe landing by using variable engine speeds, but that maneuver also failed.

Some 32 minutes after the explosion, the 747 crashed into and slid down Osutaka Ridge. Only four people survived the crash—520 others perished. That made the crash the deadliest single-aircraft disaster, and the second-deadliest crash behind the 1977 Tenerife incident.

Investigators discovered that the JAL 747 had been involved in a tailstrike incident (that is, the tail struck the runway when the plane was at too steep an angle) in 1978. The tailstrike damaged the upper fuselage near the tail. The damage was not repaired properly. It was the same area of the fuselage that failed in 1985.

The End of Supersonic Transport

Since the 1960s, England and France had flown Concorde Supersonic Transports (SSTs) as passenger airlines. In 1985, one famously flew pop star Phil Collins from a Live Aid concert in Europe to a sister concert in the United States in one day.

Supersonic passenger transport ended, however, on July 25, 2000, when an Air France Concorde taking off from Charles de Gaulle Airport hit some debris on the runway. A tire burst, and more debris punctured a wing fuel tank. The plane erupted in flames. The Concorde rose briefly, then it crashed into a hotel. The accident killed 109 people on the plane and four people on the ground. Concorde's were already being retired at the time of the accident, which permanently grounded the remaining supersonic craft.

Terrorism

Airliners have been a frequent target—or weapon, in the case of the 9/11 attacks in the United States—of terrorists.

On September 11, 2001, terrorists of the al-Qaeda terrorist organization hijacked four U.S. airliners and used them to target the World Trade Center in New York City, the Pentagon in Washington, D.C., and another target, unconfirmed but believed to be in the capital area.

The terrorists commandeered American Airlines Flight 11 and United Airlines Flight 175 and flew them into the Twin Towers of the World Trade Center, their fuel supplies igniting and causing fires that eventually buckled the towers, causing their collapse. Another terrorist group took over American Airlines Flight 77 and flew into the Pentagon. Still another terrorist band skyjacked United Flight 93, but passengers attacked them and forced the airliner down in a field near Shanksville, Pennsylvania, before they could reach their intended target. A total of 265 passengers and crew died on the aircraft. Another 2,731 people died in the World Trade Center and Pentagon.

In another of the most infamous terrorist aircraft incidents, Libyan terrorists planted a bomb on Pan Am Flight 103. On December 21, 1988, it exploded, bringing the 747 down near Lockerbie, Scotland. The incident killed 270 people, including 11 on the ground. Libyan dictator Muammar Gaddafi later admitted Libyan responsibility for the attack.

By the Numbers

An article of this length cannot possibly describe all the major accidents of the aviation age. To sum up, however, the following have been of note:

- Two accidents that killed more than 500 people (not including the 9/11 attacks in the United States)
- Four accidents that killed more than 300 people
- Twenty-two accidents that killed more than 200 people
- Seventy accidents in the top 100 worst aviation accidents that killed more than 100 people

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See Also: Air Traffic Control; Air Traffic Controller Training; Airplane Pilot Training; Airport Security; Aviation Safety, Dangerous Good Transport and; Aviation Safety, Wildlife Strikes and; Federal Aviation Administration; National Transportation Safety Board.

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Airplane Navigation Systems

The principle of airplane navigation is simple. Air navigation differs from surface navigation in that aircraft travel at relatively high speeds, thereby reducing the time to calculate their position en route. Additionally, aircraft are safety-limited by fuel capacity, and in-flight collisions with other

aircraft or terrain are usually fatal. As such, airplane navigation systems are critical to the safety of flight. The airplane navigation systems used for visual flight rules (VFR) and instrument flight rules (IFR) will vary. In the latter scenario, pilots navigate almost exclusively using the aircraft's navigation systems to ensure compliance with air traffic control.

Many aircraft are equipped with a variety of navigation systems, such as compass, automatic direction finder (ADF), inertial navigation systems (INS), flight management system (FMS), VHF Omnidirectional range (VOR), tactical air navigation (TACAN), VHF omnidirectional range/tactical air navigation (VORTAC), radar navigation, global navigation satellite systems (GNSS), instrument landing system (ILS), microwave landing system (MLS), and localizer directional aid (LDA).

Types

The magnetic compass displays the aircraft's current magnetic heading: the aircraft's direction of travel relative to the globe's magnetic field. At the Earth's poles, magnetic compasses are unreliable. Further complicating polar navigation are converging meridians at the poles. A type of navigation called grid navigation is typically used in place of magnetic navigation when flying over the polar regions. With grid navigation, a separate grid system is applied over the polar regions to aid in navigation.

Radio transmitters, commonly referred to as nondirectional beacons (NDBs), are the radio equivalent of a lighthouse. These beacons send out an amplitude modulation (AM) radio signal. The signal itself does not include a direction. However, equipped with an automatic direction finder, the aircraft can locate the direction of a radio source; the ADF automatically and continually displays the relative bearing from the aircraft to a radio station. The effective range of these beacons varies from 15 to 75 nautical miles, depending on the transmission power of the beacon.

VOR is another type of ground navigational aid using short-range radio navigation. VOR enables an aircraft to determine its position and maintain course by receiving radio signals from a network of ground beacons. The bearing is displayed in the aircraft. The line of position is the "radial" from the VOR. The intersection of radials from two different

VOR stations on a chart provides the aircraft position. VOR stations have a relatively short range, typically 200 miles or less.

TACAN is a navigation system used by military aircraft that provides the aircraft with bearing and distance, known as "slant-range" to a ground or ship-based station. It is a more accurate version of the civilian VOR/DME system. The DME (distance measuring equipment) portion of a TACAN is available for civilian use at VORTAC stations where VOR is combined with TACAN to provide VOR/DME information. Distance from the station is provided by measuring the time required for the signal exchange from the station to the aircraft. Aircraft equipped with TACAN can use this system for en route navigation and nonprecision approach landings.

Variations of the ADF/VOR/TACAN and VORTAC displays include horizontal situation indicators (HSIs), radio-magnetic indicators (RMIs), and bearing-distance-heading indicators (BDHIs), all of which overlay bearing information onto a compass card to display relative bearing to a radio source with respect to the aircraft's heading.

Inertial navigation systems work by providing a computer with the aircraft's present position. Accelerometers and gyroscopes measuring changes in acceleration and direction provide data to the computer. This data is then used to constantly measure and recompute changes in speed and direction to provide an accurate estimation of the aircraft's present position.

Over long distances, inertial navigation systems can accrue small amounts of error. This error can be corrected by taking a fix and updating the present position of the inertial navigation system in flight. The data from inertial navigation systems can also be combined by aircraft computers with other navigation systems, such as global navigation satellite systems, to obtain a blended, more accurate navigation position.

Many newer aircraft are equipped with a flight management system (FMS) consisting of a flight management computer (FMC) and one or more control display units (CDUs), and an internal navigation database. The FMS utilizes aircraft sensors and the navigation database to compute and display aircraft position, performance data, and navigation information during all phases of flight. The navigation database usually contains regional or

worldwide coverage and typically includes information on navigation aids, airports, runways, waypoints, routes, airways, intersections, departures, arrivals, and instrument approaches. Navigation databases require periodic updates to ensure the data are current.

With radar navigation, the aircraft sends a pulse of microwave energy and the energy is reflected by objects in its path. Pulse is amplified and converted by a receiver using a cathode-ray tube (CRT). Additional features have been added such as weather avoidance and terrain following. The radar produces an image of terrain and man-made features such as cities with respect to aircraft position, which can be used to generate a visual navigation aid. Radar can be used for both en route navigation and approaches.

Global navigation satellite systems (GNSS), more commonly known as global positioning systems (GPS), use a system of space-based satellites to provide highly accurate three dimensional position, velocity, and time to aircraft. GNSS/GPS can be used for both en route navigation and landing approaches.

Instrument landing systems provide an approach path alignment and descent to the final approach of a runway. The ground equipment consists of two highly directional transmitting systems, optional DME transmitters, and marker beacons or compass locators. The directional transmitters are known as the localizer and the glide slope is displayed on the cockpit instrument panel(s).

Microwave landing systems provide precision navigation guidance for exact aircraft alignment and descent during approach to a runway by integrating azimuth, elevation angle, and range (DME) information to provide precise aircraft positioning. Similar to an ILS, MLSs use an elevation station instead of glide slope antennas, and instead of a localizer antenna MLSs use an azimuth station.

Localizer directional aids are similar to localizers (LOC) except that they are not always aligned with the center of the runway. Terminal instrument procedures (TERPs) requires localizer signals to be within 3 degrees of the runway alignment. If this alignment exceeds 3 degrees, the localizer is identified as a localizer directional aid. Generally, LDAs are considered nonprecision approaches unless additional information is published. Note:

LOCs/LDAs are abbreviated LLZs by the International Civil Aviation Organization (ICAO).

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See Also: Airplane Pilot Licensing; Airplane Pilot Training; Airplanes; Automated Landing Systems, Airplane; Collision Avoidance Systems, Airplane; GPS.

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Airplane Pilot Licensing

In the early history of flight, there were no regulations, and pilots flew without licenses. Neither planes nor flight schools were certified, and those interested in learning to fly could do so for around \$100. The Air Commerce Act of 1926 required aircraft to be inspected and those who flew them to be tested for aeronautical knowledge and physical fitness. By October 1928, 3,659 licenses had been issued in three categories: air transport, industrial, and private. The highest level required only 100 hours of solo flight. More than three-quarters of a century later, according to the Federal Aviation Administration (FAA), there are more than 618,000 certified pilots in the United States. Air Transport Pilot certification requires a minimum of 1,500 hours as a pilot.

The Beginning of Licensed Pilots

William P. MacCracken, Jr., assistant secretary of commerce for aeronautics, received the first pilot's

license issued by a civilian agency of the U.S. government on April 6, 1927. Orville Wright refused the honor, saying that he no longer flew and indicating that a federal license was unnecessary to show that he had been the first man to fly. Unlicensed pilots were given until May 1, 1927, to apply for a license. The new air regulations stated that after that date it would be illegal to fly “any aircraft registered as an aircraft of the United States” without a certificate. Charles Lindbergh was issued license no. 69 in time for his historic solo flight across the Atlantic on May 20–21, 1927. Phoebe Fairgrave Omlie received transport license no. 199 on June 30, 1927, probably the first woman granted a pilot license by a civilian agency of the U.S. government.

MacCracken was licensed as a private pilot. Although he had experience as an Army pilot in World War I, regulations required only 10 hours of solo flight, two of which must have been within 60 days immediately preceding application, to license a private pilot. Air transport pilots were initially required to have 100 hours of solo flight, double the number required of industrial pilots, and to pass a physical examination every six months, but within five years, technological advances led to new requirements. On May 16, 1932, the official *Air Commerce Bulletin* announced that, effective January 1, 1933, all pilots on scheduled interstate passenger service must secure a new rating for transport pilots. The new rating would be awarded only after pilots demonstrated their ability to use airway navigation aids and to fly specified maneuvers guided entirely by instruments. By the end of 1932, 330 pilots had received the new rating. Fifty years later, the estimated number of certified airline transport pilots was 73,741.

Pilot Training

Some pilots receive their training from accredited, degree-granting, postsecondary institutions that range from technical schools to universities. For example, students at top-ranked Embry-Riddle Aeronautical University, which offers 35 degrees, including a Ph.D. in aviation, pay more than \$30,000 a year to attend the largest and oldest aviation school in the world. Some pilots receive their training while in the military, but most pilots are trained by flight instructors at flight schools approved by the FAA where basic flying lessons, ground instruction, and related fees run around \$10,000.

FAA-approved flight schools fall in two categories based on the part of FAA regulations under which they operate. Part 61 schools have greater flexibility. Instructors are not required to follow a syllabus. They must cover material specified by the FAA, but they are free to do so based on student progress. Students in these schools are not required to complete a formal ground school program, although they must pass the written and practical examinations required by the FAA. Part 141 schools are more structured, operating under an FAA-approved syllabus that is adhered to throughout training. Students are required to complete a specified number of hours of ground instruction in a classroom setting or individually with a flight instructor. The FAA requires students in Part 61 schools to have a minimum of 40 flight hours to receive certification as a private pilot and students in Part 141 schools to have a minimum of 35 hours. Since the national average for initial certification as a private pilot is 65 to 70 hours, this difference is insignificant. A difference exists in flight hours to be certified as a commercial pilot as well. Part 61 schools require a minimum of 250 hours, whereas Part 141 schools require only 190 hours.

Pilot Certification

The FAA has the authority to grant pilot certificates in six categories. “Certificate” is the word used in the official authorization, but “license” is used informally and interchangeably. The categories include student pilot, recreational pilot, sport pilot, private pilot, commercial pilot, and airline transport pilot. On certificates other than student pilot, ratings are specified as the individual completes training and certification requirements in such areas as aircraft category (airplane, rotocraft, glider, etc.), airplane class (single-engine land, single-engine sea, multi-engine land, multiengine sea), and instrument (for private and commercial planes).

Although a student pilot certificate is not required to take flying lessons, any individual who flies solo must have a valid student license. The only requirements are that an individual be at least 16 years old (14 years old for a glider or balloon); read, speak, and understand English (required for all certificates); and hold at least a current third-class medical certificate. A third-class medical certificate affirms that the applicant has the vision, hearing, and general physical condition to operate an aircraft safely and is free of mental disorders

and substance dependence. Both the student pilot certificate and the medical certificate are valid for 60 months, for those under 40 years of age, and 24 months for those over 40 years of age.

The Sport Pilot Certificate, the only one that does not require a medical certificate, was created in September 2004 to license those interested in flying light sport aircraft. A sport pilot may exercise flight privileges in one or more of the following: single-engine airplanes, gliders, airships or balloons, gyroplanes, powered parachutes, or weight shift control aircraft. He/she must be at least 17 years of age and log a minimum of 20 hours of flight time: 15 of dual instruction with a qualified instructor, two cross-country dual instruction flights, and five solo flights. This category is growing in popularity at the cost of recreational pilots. In 2011, 4,350 sport pilots held active certificates, compared to 210 recreational pilots.

There were 195,650 certified private pilots in the United States in 2011. Depending on the ratings acquired, private pilots can fly almost any plane under visual flight rules for any noncommercial purpose. In addition to the standard requirements of command of English, medical certificate, and written examination of knowledge and actual flight, the private pilot, who must be at least 17, must accumulate a minimum of flight hours with an instructor and solo. Part 61 training requires 40 hours (20 with an instructor and 10 solo); part 141 training requires a minimum of 35 hours (20 with an instructor and 5 solo). Both require night and cross-country flight to be included in the total.

To be granted a commercial pilot certificate, an individual must be 18 years old and hold a private pilot license and second-class medical certificate, which requires that all the criteria for a third-class certificate be met in addition to more stringent vision standards. Second-class medical certificates must be renewed annually. Flight requirements under Part 61 regulations include a minimum of 250 flight hours as pilot, with 30 hours accompanied by an instructor and 10 solo hours. Other flight requirements include specified amounts of day, night, and cross-country flight. Part 161 regulations specify a minimum of 190 hours, 55 hours with an instructor and 10 solo. As with other certificates, the applicant must pass both a written and a practical test.

To be eligible for an airline transport pilot certificate, the applicant must be 23 years of age, be of good moral character, hold a commercial pilot

license with an instrument rating, pass a stringent written and practical test, and have a minimum of 1,500 hours of flight time as a pilot. The required flight time must include 500 hours of cross-country, 100 hours of night flying or 75 hours plus 45 full-stop landings at night, and 75 hours of instrument flight time or 50 flight plus 25 simulator hours. The airline transport pilot must also hold a class one medical certificate, which requires the applicant to meet all criteria for third- and second-class certifications plus have an electrocardiogram that shows normal heart function.

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See Also: Airline Industry; Airline Pilots and Crews, Labor Issues of; Airplane Pilot Training; Aviation, Commercial/Business; Aviation, Private.

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Airplane Pilot Training

Pilot training is one of the paramount missions of the Federal Aviation Administration (FAA). Steady advances in technology, constant updating of aircraft-type instrumentation and airfield-layout databases, and continually improving user interfaces have led to near-universal dependence on flight simulators as an integral part of every pilot's training.

Flight simulators, with their capacity to economically and rapidly test the widest range of conditions and scenarios, are also an indispensable part of aircraft prototype development. Additionally, the analysis of pilot and airplane performance monitoring data is increasingly integrated into the ongoing evaluation of individual pilots and aviation companies; this in turn leads to improvements in

subsequent training. In essence, pilot training is a continually improving and updating process, and the FAA's role is central to its quality and reach.

Military Impetus

From the earliest days of machine-powered flight, flying enthusiasts have sought ways to share knowledge, test new designs, and refine approaches to piloting. At the same time, the quest to reduce accidents, fatalities or injuries, and property loss has been a constant. Rapid and sophisticated advances were made during World War II, as national governments provided the impetus, personnel, and funding for research and development of military combat and support aircraft flight training devices and procedures. Innovation led to the design of a variety of celestial navigation simulators as well, some so large they were constructed inside 45-foot-high silos, to provide crew training in nighttime navigation by the stars.

As other technologies related to aviation leaped ahead, the engineers crafting flight simulators had to keep pace and adopt appropriate mock-ups and stand-ins into their own designs. Radar research and development, for one example, led to the need for training devices that incorporated systems to simulate visual contact, enemy aircraft identification and apparent course, target acquisition and lock-on pathways, and other factors. In the United Kingdom, the use of synthetic radar trainers, as they were called, was estimated by the Royal Air Force to have saved as much as \$50 million in aviation fuel over the course of the war.

In the years following World War II, pressures to innovate were intense, and the momentum in flight simulator design and production, rather than slowing down, actually accelerated. Both military and commercial endeavors expanded at full speed all around the aviation sphere; the development of flight simulators grew along with this general burst of industrial aeronautical experimentation and enterprise.

As military aircraft grew in terms of size, mission distance, payload, and endurance capacity, the flight simulators also expanded and diversified. Many of these training units dropped the use of motion simulation in favor of a focus on the myriad newly developed electronic switches, controls, communications devices, and other systems that flight crews had to master. Human trainers became expert at inventing ways to simulate emergencies,



A U.S. Navy F/A-18 pilot training in a flight simulator at a naval air station in Lemoore, California. Flight simulator training can cost as little as 2 percent of the expense of training in aircraft.

whether derived from extreme weather, equipment malfunction, misunderstood commands, enemy actions, or other sources. The movements, decisions, and communications of the trainees were observed live and up close, typically through open-backed installations, via mirrors, or through frosted window glass.

The growth of civilian flight simulators also boomed during this period, with aviation manufacturer Curtiss–Wright taking the lead. The simulators from this production resource incorporated an enhanced measure of feedback in the sense that some of the instrumentation would respond or change appearance in reaction to the actions of the trainees. This type of improved feedback, along with the earliest real tri-axis cockpit movement simulation, became widely adopted by commercial aviation training instructors and flight schools.

These commercial aviation pioneers of simulator technology improved and invested in the “virtual

reality” of their eternally grounded equipment, as is the case today, because even with such major investment the cost was far below that of actual flight training in fuel-consuming and damage-risking airborne craft. Research has suggested that the use of flight simulators for training can yield a cost structure as little as one-fiftieth, or 2 percent, of the cost of using operating aircraft for flight training.

For its part, the FAA emphasizes the use of flight simulators in its goals for improved aviation safety in the United States, and for U.S.-based pilots specifically, through the activities of its National Simulator Program (NSP). This formalized structure provides standards for simulator device design and usage procedures, instructor and simulation manager qualifications, and various certification levels for trainees. The NSP also maintains a suite of international agreements on these and similar rules and standards in bilateral compacts with foreign-based companies and civil authorities.

Technological Advances

In the 1960s, the visual displays in flight simulators became more and more convincing; cockpit motion activation was also moving into the realm of the near-real. Use of projection and collimated (parallel-beam) light enhanced the depth perception aspect of the visual experience, while hydraulics blended axial motion into highly accurate mimicry of aircraft motion.

Furthermore, it was in this decade that computing power began to be unleashed into the field of flight simulator technology. This power enabled the crafting of a vast series of conditions, scenarios, and prototype alterations and the strongest visceral feedback yet achieved. It also gave instructors the ability to customize training sessions to the varied abilities and skill levels of the individual trainees. Instructors could monitor sessions more intimately, predict challenges and errors, and introduce test elements more in tune with the background experience and flight competency goals of many types of trainees.

As the 1970s dawned, engineers found ways to completely envelop the flight simulator trainee in an enclosed machine that exuded real aircraft sights, sounds, and motion—and that provided feedback to the trainee’s senses that was exactly close to what he or she would experience in the air. The instructor’s observational abilities, control

capacity, and reporting systems kept enlarging and improving as well, thanks to computer-aided interfaces and data streams.

Electric motion and control loading technology have, in the decades since then, in many cases replaced the use of hydraulics in flight simulators. Attendant savings in such models today stem from easier maintenance and smaller building space requirements, lower environmental cost and energy consumption, less noise, and reduced personnel costs to support the systems.

A technology that had started out with wooden half-barrels rocked by muscular assistants had morphed into full-size cockpit interiors that integrate 50 years of actual aeronautic innovations to produce all the variables of altitude, gravity forces, system glitches, and communications of the real things—giving instructors the power to prompt, track, and tweak the learning curve of the new generation of pilots and flight crews. In fact, flight simulators were increasingly used to train aircraft mechanics and maintenance personnel, as well as pilots and aircrew.

The adoption of flight simulators for training has led to further integration of simulators with the design, testing, and construction of new aircraft. In many cases today, pilots train on simulators with new airframe designs even before the first prototypes of aircraft are ready to be test flown. Thus, when new aircraft are ready for introduction, the availability of skilled crews can shorten the fleet activation time. This feedback loop of actual and simulated aircraft performance yields still more cost savings—as well as informing the aircraft manufacturers of potential final-stage alterations in aircraft design and operation and suggesting retrofitting ideas.

Standards and Certifications

In parallel with the technological evolution of flight simulators, the regulatory mechanisms for pilot certification and aviation standards have kept pace. The FAA has incorporated flight simulator training into its rules, guidelines, and enforcement strategies to the point where the vast majority of pilots have trained on simulators.

Aspects of the flight simulator field covered by the NSP include manufacturing processes, approved data standards, ways and means of evaluation, modifications and upgrades to equipment as

well as to usage, enforcement and review flow, and negotiating cross-border agreements.

The NSP encompasses the Simulation Quality Management System (SQMS), which enumerates assessment tools and program requirements that the FAA has identified as key to the NSP mission of continual improvement of flight simulator training and thereby to the constant dedication to its fundamental mission of improving safety in aviation. The SQMS is particularly focused on the “output” of the system, that is, “credible flight crewmember training, evaluation, or meeting flight experience.”

This output is produced in two ways. One is by certifying the personnel engaged in flight simulator training management. The other is by keeping the gains of civil aviation innovation, practice, and research flowing into the flight simulator training field. One mechanism of achieving this second outcome is the designation of simulator evaluation specialists to serve on the Flight Standardization Boards and Flight Operations Evaluation Boards administered by the FAA. This keeps managers of flight simulator programs up to date on changes and trends in aviation safety and helps them devise ways to adopt these trends into their training management regimes.

The FAA through the NSP embraces a very comprehensive approach to simulator use. Programs are organized across a range of disciplines and draw on the widest scope of FAA-responsive fields and competency areas, such as through fixed-wing and helicopter branches; through job descriptions inclusive of flight engineers, flight navigators, aircraft dispatchers, and others; through intensive focus on international civil aviation aircrew training issues; and through integration of knowledge updates from the fields of navigation, communications, surveillance, airspace systems engineering and research, and instrument flight operations procedures and standards.

One factor driving the adoption of flight simulator training is the continuing expansion of the fleet of technologically advanced aircraft (TAA) as opposed to what the aviation industry refers to as legacy aircraft, or those with less aerodynamic design and fewer digital, electronic, electromechanical, or smart-material elements. With each new TAA model introduced, the manufacturers and programmers of flight simulators are compelled to keep pace. Similarly, pilots and pilots in training

must turn to these enhanced simulator stations in order to remain up to date in their skill sets. Operators of flight schools therefore operate in a generally friendly competitive environment in which they seek to maintain competence and contemporary experience levels appropriate to an always-changing profession.

Online Developments

The great allure of flight has over the years attracted millions upon millions of individuals to test their skills, resourcefulness, and imagination. This consistently spreading popularity has in turn convinced the software developers of entertainment and utility programs for the personal computing world to invest substantial quantities of creative resources in the development of such now-familiar programs as Microsoft Flight Simulator. This particular product, initiated as an early personal computer-based video game with its first version introduced in 1982, has helped at least two generations of pilots find their way ultimately into real airborne cockpits.

Microsoft Flight Simulator also spawned many competitors, which in turn helped spur acceleration in the quality, verisimilitude, adaptability, and eventually some components of a certification-level flight simulator experience that can be taken in the comfort of one's home. Indeed, the FAA and its like agencies in other parts of the world now encourage and accept some home flight simulator training hours as part of their certification course requirements.

Alternatives to the Microsoft product line have included FlightGear, an open source, free simulator program known for incorporating some National Aeronautics and Space Administration (NASA) modeling resources and operable on systems including Linux, Mac OS, Windows, and FreeBSD; X-Plane, a simulator program adapted to a range of software platforms and hardware types, including Mac OS, Linux, Windows, and Android; and a wide range of other products of varying degrees of complexity, realism, game play value, and educational value.

With the 1990s advent of the Internet as an increasingly central feature in people's daily lives, the wide adoption of personal computer flight simulators tended to generate online communities of players who reviewed, passed along, modified, and

team-played the various titles, and even created their own.

In turn, this type of home-based activity seems to have meshed well with the hobbyist or enthusiast mentality of much of the private aviation population, giving rise to such organizations as the Virtual Air Traffic Simulation Network (VATSIM). This group, with some 250,000 members claimed worldwide, has earned the respect of many in commercial and even military aviation, and the FAA has on occasion used VATSIM's online flight simulation network capabilities for its own research. VATSIM and other organizations like it, such as Angle of Attack and the AVSIM Community, conduct the bulk of their activities online but do hold a number of well-attended conventions and events where flight simulator technology and technique are explored and many far-ranging topics related to aeronautics, aviation, and computing are analyzed and discussed along with ideas on education, safety, and regulatory issues.

The Installed Base

Student pilots may start their journey to pilot certification on home-based personal computers, but at some point they will graduate to flight simulators operated by flight schools of various physical and business configurations. These schools must meet FAA requirements for instructor and technology certification, as stipulated through the NSP.

Following their initial success, avid fliers will return to the simulator at different stages in their aviation career, visiting different parts of the far-flung installed base of flight simulators. These may be in certified flight simulator stations operated by privately run flight training schools and institutions, in facilities built and run by aviation and aerospace manufacturers or by the various branches and units of the military, or in many cases by the major airlines themselves.

For example, Delta Air Lines, the world's largest commercial carrier, operates a well-refined system of simulator-based courses through its in-house flight simulator stations. These are directed by the Delta Business Programs division's Training and Consulting Services unit. One component is the Delta Aircrew Training Centers in Atlanta, Georgia, and Minneapolis, Minnesota, where pilots are trained to industry standards and tested on recurrent proficiency checks for at least 12 aircraft from

manufacturers Airbus, Boeing, and McDonnell Douglas. Delta professional pilot training staff use more than 30 flight simulators, both fixed base and full motion, in this system.

NASA, too, has its flight simulators and, befitting the world's greatest training organization for astronauts, NASA is said to operate the world's largest single flight simulator. Installed at the Ames Research Center in Mountain View, California, the NASA Vertical Motion Simulator (VMS) is used to "explore, define, and solve issues in both aircraft and spacecraft design," according to the space agency. The VMS is customizable to any aerospace vehicle, "whether existing or in the design stage." At various times and for specific missions, simulated vehicles have included the space shuttle, fighter jets, helicopters, and a blimp.

The VMS incorporates five portable interchangeable cab units and a motion base set within a silo more than 60 feet high and 40 feet wide. Out-the-window graphics, high-fidelity flight controls, and exactly accurate response mechanisms in the VMS are crafted and refined in the Virtual Lab connected with the facility. NASA operates this advanced flight simulator complex in an integrated manner with its separate FutureFlight Central and Crew-Vehicle Systems Research Facility in order for both to provide simultaneous cockpit and air traffic control perspectives and to analyze system-level concepts across multiple operational domains.

In November 2013, the FAA promulgated its final rule, or set of amendments, to the Airline Safety and Federal Aviation Administration Extension Act of 2010. This latest rule set was designed to "ensure enhanced pilot training" both in initial training phases and through remedial training protocols. In its ruling, the FAA explicitly identifies improvements to flight simulator operations and standards as key to the future of pilot training. The act now mandates, for example, that air carriers "use data to track remedial training for pilots with performance deficiencies, such as failing a proficiency check or unsatisfactory performance during flight training."

The act also addresses perceived training gaps needed to deal with conditions such as wind gusts, crosswinds, stalls, upsets, and various runway situations. Many of these performance and training issues have been uncovered through the analysis of data collected in real time during actual flights, thanks to the

online capture of flight data. The new rule announcement by the FAA specifically notes that air carriers will have five years to implement all the changes, as this time is judged necessary for “software updates to be made in flight simulation technology.” While the cost to the industry of implementation is estimated at up to \$354 million, the FAA has projected the benefit at nearly \$700 million.

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See Also: Aeronautics; Air Traffic Control; Air Traffic Controller Training; Airplane Pilot Licensing; Automated Landing Systems; Airplane; Aviation, Commercial/Business; Aviation, Private; Federal Aviation Administration.

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Airport Administration

Any airport in the United States is part of a transportation network that is characterized by its immense scope and complexity. This complexity exists at several levels: within the airport as a single entity, as part of the aviation network, and as a part of the larger national transportation network. According to the U.S. Federal Aviation Administration (FAA), there were over 19,000 airports in the United States as of 2011. Of these, approximately a quarter are open to the general public. Slightly over 500 airports are classified as commercial service airports that serve a minimum of 2,500 passengers each year.

At airports complexity exists on several levels. There are internal operations and those in coordination with other airports on both the national and international levels (this is particularly true of airports that are part of “hub-and-spoke” networks). There are interactions and coordination required with ground transportation either as means of conveying logistical support to the airport or sending goods to other transportation centers (as is the case with services such as FedEx or UPS).

Further, there are a wide variety of business operations that exist at airports either as part of the required operational infrastructure, air carriers located on site, support for air carriers, or providing goods and services to passengers. Then, there

are aspects of running an airport that are political, economic, social, or environmental in nature. They exist and are distinguished by the geographical location of an airport and its surrounding topography and population centers. Finally, there is the complexity of dealing with governmental and non-governmental organizations at all levels.

Airport Administration Organizations

Airport administration is the means by which an organization oversees, manages, and implements every one of the tasks required to ensure the safe, economical, and effective operation of an airport. The administration organization (sometimes also referred to as the airport operator or management) exercises management and control over the airport. It has complete responsibility for every aspect. It can be either a governmental or a purely commercial organization, although it should be noted that there is currently (2013) only one airport in the United States, at Branson, Missouri, that is managed by a purely commercial entity.

Airports can be managed and operated as individual sites or by organizations that manage several airports (an instance, frequently found where port authorities are the governing body).

Airports are sometimes managed by a metropolitan governmental entity (directly or the authority may be delegated to an organization that reports to the municipality), a county, or directly by the state. The Colorado Springs, Phoenix Sky Harbor, and Salt Lake City airports are owned and operated by the cities where they are located. Rochester, New York, and Cincinnati/Northern Kentucky airports, on the other hand, are managed by counties. Honolulu airport is owned and operated by the state of Hawai'i.

Some airports are managed by autonomous airport or port authorities that conduct all management, administrative, and financial operations. They exercise a great deal of independent management and operations, although they do have regulatory obligations to the federal, and sometimes the state, Department of Transportation. Louisville International and Indianapolis airports are examples of airports run by airport authorities.

Finally, there are airports that are managed by port authorities. In Massachusetts, Logan (Boston) and Worcester airports as well as Hanscom Field are managed by the Massachusetts Port Authority (Massport). Massport, which also manages

the shipping at the Port of Boston, is a state-level agency. Its revenues of approximately \$8 billion annually have ensured that it operates at a profit and for that reason, it can operate without tax-funded appropriations.

Another instance of a port authority managing airports is the Port Authority of New York and New Jersey (PANYNJ). Existing since the early 1920s, the PANYNJ has managed tunnels, bridges, bus terminals, port commerce, rail transit, and airports for the New York City metropolitan area. Currently, it manages five airports: JFK, LaGuardia, Newark (New Jersey), Teeterboro (New Jersey), and Stewart Airport located near Newburgh, New York.

Administration and Regulations

Regardless which type of organization administers and manages the facility, airport administrators must comply with the regulations of both federal and state organizations. On the federal level there is the Federal Aviation Administration (FAA), one of 10 administrations that are part of the U.S. Department of Transportation (DOT). The FAA's stated mission is "to provide the safest, most efficient aerospace system in the world." It is the regulatory agency for all aspects of air travel.

For airport administrators, however, the most critical area of FAA activity is the process by which airports apply for, receive, and work to keep their Airport Operating Certificates. The list of criteria that must be met provides an insight into the types of issues and operating areas that airport administrators must address. Usually, FAA inspections are performed annually, but there can also be unannounced inspections. In any case, the criteria must be constantly kept in mind by airport administrators in order to ensure that every aspect of the site operates as it should. Requirements are disseminated by the FAA in a manner to ensure that administrators are aware of the requirements and can plan and implement maintenance and new initiatives.

Inspections confirm that all FAA administrative paperwork has been kept up to date and is complete. Safety inspections of various sorts are conducted. Among these are inspections of the runways (because of the force of a plane's landing on the runway, cracks and potential buckling are causes for inspection and maintenance). The areas around the runways, particularly where there is wildlife (animal strikes are a cause of concern and

have been the cause of several crashes) or where individuals could inadvertently access the runway are inspected as well. Lights and signs on the runways are also inspected. Because fire is always a possibility at an airport, rescue and fire-fighting drills are conducted and evaluated by federal inspectors. Fueling facilities and night operations are also inspected.

The specific ways in which airport administrators interact with the state aviation authorities varies from state to state depending on what the state legislature has deemed to be appropriate for those state agencies. In most instances, the state's department of transportation aviation section regulates, oversees, funds, or otherwise supports several areas that directly affect the operation and management of airports.

In North Carolina, the state's DOT has an Aviation Division responsible for all aviation functions regarding state system planning, airport and aviation system development. The Aviation Division also provides funding to communities for constructing and improving airports throughout the state. In New Mexico, the DOT's Aviation Division has several objectives. Those objectives of most interest to airport administrators are obtaining financial grants to improve aviation infrastructure, supporting the development and maintenance of airports, and implementing aviation safety initiatives. Airport administrators in Florida work in cooperation with the Aviation and Space Ports Office which is part of the state DOT. This office performs inspections, licenses airports, supports airport development and maintenance, and regulates some construction until that responsibility can be assumed by local authorities. In New Hampshire the Bureau of Aeronautics (part of that state's DOT) has the mission of planning, constructing, and maintaining airport facilities (note this in effect means support and not actually performing the maintenance). Its objectives not only emphasize safety but also ensure that the part aviation plays in that state's tourist industry is promoted.

Airport administrators must also work with municipal governmental organizations, although the nature of that relationship can vary widely. When the local government (town, city, county) is the owner and the operator of the airport, conformance to regulations is quite straightforward. As the owner, the local municipality or county makes the rules for

its own airport, and administrators must ensure that they are followed. When the airport operates under an authority other than the local government, administrators must sometimes negotiate with local authorities or work out how airport operations will be within the regulations of that authority.

Sometimes, local organizations that are not part of any government must also be recognized by airport administrators, and working relationships with such organizations must be established and maintained. These other parties may include civic or environmental groups that voice their concern over issues such as noise pollution.

Administration and Management Operations

Management and administration of an airport, regardless of size, is a complex affair. While the scope and amount of detail and nature of issues can vary, most airport administrators face many of the same issues in ensuring that the airport under their management functions correctly. Some of these issues are obviously difficult. Others may seem to be easily resolved by implementing technology but, without proper planning, they can create even larger problems (such as the 16-month delay of Denver airport's opening because of a malfunctioning baggage handling system). Long-range planning for facilities enhancements, additions, or maintenance to include the all-important financial components is a part of every administrator's job.

There are infrastructure issues that must be managed as well. These include runway design, maintenance, and construction, and lights and other navigation aids. These items are funded by the FAA but their maintenance is the responsibility of the airport. Infrastructure also includes local transportation to and from the airport that has a direct effect on how well the airport serves its passengers. Depending upon the location, this may include roads and commuter rails, such as those found in Atlanta and at Reagan National Airport in Washington. Local transportation system capabilities such as taxis, limousines, and buses are another area of concern for administrators—not only their availability but also how the airport makes that transportation accessible.

The entire physical plant at the airport must be maintained and at times expanded. This includes hangars and other facilities that are made available to

air carriers, as well as parking and buildings used by passengers (terminals and concourses). The activities required to provide a place for amenities for passengers such as services, food and drink, and goods for purchase are also part of the facility operation.

Safety and security and coordination with the Transportation Security Administration (TSA) for checking passengers are other areas of coordination. Local security and safety is the responsibility of the airport administration, regardless whether it is provided by private security, local law enforcement, state police, or, as occurred shortly after the 9/11 attacks, the National Guard. Emergency plans for any safety or security contingency must be created and implemented by the administration.

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See Also: Airline Flight Reservation and Ticketing Systems; Airline Flight Scheduling; Airport Operations and Marketing; Airport Planning; Airport Security; Aviation, Commercial/Business.

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Airport Gate Assignment Problems

One of the key issues in air travel is assigning gates in an airport to individual aircraft. Finding an optimal solution to this problem is becoming ever more critical as air travel increases and airports become more congested, increasing the pressure to use space efficiently to increase the number of flights

that can be handled at an airport while also preserving a reasonable experience for passengers on those flights. The goal of the Airport Gate Assignment Problem (AGAP) is to optimize gate assignment, taking into account many factors. It is an extremely complex problem, classified in mathematical terms as an NP-hard problem (nondeterministic polynomial-time hard) problem, meaning that there is no known algorithm for optimizing it within a practical amount of time.

The Airport Gate Assignment Problem

The Airport Gate Assignment Problem is concerned with optimizing gate assignment, with particular regard to passengers who must connect from one flight to another in a limited period of time. The basic concept behind AGAP is simple—each plane must be assigned to one gate, and no two planes can be assigned to the same gate at the same time—but in reality the problem is quite complex because of the number of factors involved.

Because most airlines today operate on a hub-and-spoke system, where most flights are to and from one or more hubs, and flying between two nonhub points usually requires flying to a hub, transferring to another plane, and then flying to one's destination, gate assignment is a particularly important aspect of airline management. The problem is complicated by the fact that normally different gates, and perhaps even different terminals, may be used for the arriving and departing flights. While passengers tend to prefer tight connections, in order to spend less total time on their flight (and less time waiting in the airport), booking systems require a specific amount of time between two connecting flights in order to raise the probability that the passenger can actually make the connection; however, if the time allowed is near the minimum, it raises the probability that any delay or disruption will cause the passenger to miss the connection, thus introducing further disruption to the system.

The "turn" is the period of time an airplane is on the ground between arriving and departing flights, and an airplane must be assigned to a gate for every turn. Gate assignment is based on several factors, including the geography of the specific airport (including walking time between gates, and the distance baggage must be transferred between flights), the size of the aircraft, the number of passengers on a flight that must connect with another flight,

and the amount of time they have to make that connection. Gate assignments also play a key role in maintaining flight schedules—one delayed flight can disrupt many other flights due to constraints in the facilities and equipment available—and for this reason “gate rest,” meaning a period of time when a gate is idle between the departure of one flight and the arrival of the next, is included in AGAP models.

Approaches

Initial approaches to AGAP applied quadratic assignment techniques to the AGAP, but these approaches require substantial computing time to arrive at a solution and have difficulty handling uncertain information and multiple performance criteria, both of which are absolutely basic to the real operations of air travel. More recent approaches use knowledge-based approaches to developing heuristics, incorporating expert knowledge and developing a system of rules that can create optimized gate assignments and also make new assignments quickly when required due to changing circumstances or unforeseen events like mechanical failures and weather delays.

For instance, Soi-Hoi Lam and colleagues developed a system, InGates (Intelligent Airport Gate Assignment System), based on analysis of a real-time AGAP. InGates uses an intelligent agent to determine candidate gates for each airplane, using production rules based on factors including the compatibility of particular gates and particular planes, airplane capacity, conflicts between adjacent gates, and transfer distances for passengers and baggage. The goals for an optimal solution include minimizing delays, transfer distances for baggage and passengers, and changes to pre-established assignment, and maximizing use of gate with aerobridge facilities. Results from a test data set from Singapore’s Changi Airport, including over 200 flights in a 24-hour period, found that InGates could assign aircraft to gates in a manner similar to manual assignment methods and could do so quickly while requiring minimal computing time.

Common Use

Many airports were constructed on the exclusive use model, meaning that each airline had its own dedicated space for gates, check-in counters, baggage retrieval, etc. However, more recently the common use model has become popular as a



A gate lounge area at Edinburgh Airport in Scotland in 2009. Because one delayed flight can disrupt many other flights, “gate rest,” or idle time between the departure of one flight and the arrival of the next, must be considered when assigning gates.

means to provide services at lower cost, use airport facilities more efficiently, and provide a better passenger experience. The advantage of the dedicated use model, for the airline, is that they have maximum control over their operations, while for the airport operator, they are guaranteed to be paid for the space whether the airline is using it or not. However, the dedicated use model is less flexible, because often space dedicated to one airline is not used, while other airlines may not have sufficient space to meet demand for their services.

The common use model, which is still less common in the United States than in some other countries, actually represents a continuum of choices, from exclusive use (the most restrictive), through mixed use, preferential use, and common use (the least restrictive). In the full common use model, assignments for gates and other facilities are made

without any preference to the particular airlines but with the goal of maximizing efficient operation.

While common use introduces flexibility, it also increases the complexity of the problem, because more flights and gates must be considered all at once, as opposed to each airline managing just its own planes and gates. This places a great burden on the airport operator, who must not only make the assignments but also monitor conditions within the airport and adjust assignment if necessary (for example, if flights are delayed or cancelled). Some argue that this is in fact an additional advantage of common use systems—by taking responsibility for gate assignment and facilities management away from airline operators, they are free to concentrate on providing air transportation, which is their specialty.

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See Also: Air Traffic Control; Air Traffic Flow Management; Airline Flight Scheduling; Airport Administration; Airport Hubs; Airport Operations and Marketing; Airport Passenger Terminals; Airport Planning.

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Airport Hubs

Airports are often classified, planned, and operated as part of a hub-and-spoke system of air routes, as opposed to a point-to-point model. The functionality of hub-and-spoke is largely based on the fact that travelers change planes at the hub airport in order to reach their final destination at another airport at the end of one of the spokes. The same principle applies to the operation of cargo air traffic.

Varying Definitions and Terms

The Federal Aviation Administration (FAA) in its National Plan of Integrated Airport Systems (NPIAS) defines the hub classification of an airport as either large, medium, small, or non. These classifications are based solely on the number of enplaned passengers who use the airport on an annual basis. Across the airline industry, however, the term *hub* is used more generally and refers to any airport where most of an airline's passengers use the airport to transfer between flights in order to reach their destinations.

Other terms in use by specific airlines or by airport industry officials include "key city" and "focus city," although these sometimes refer to somewhat different situations. Focus city originally specified a destination airport rather than one where connecting flights were assembled; however, the term's use by various carriers to promote certain flights has led to its more general adoption to refer to either a destination or transfer airport that an airline uses on a fairly heavy basis. In a related manner, key city is loosely defined but usually refers to a smaller hub airport that an airline nevertheless uses somewhat heavily and seeks to promote as both a transfer point and a destination.

Some hubs are strongly identified with major carriers and even serve as headquarters for a given airline. For instance, Delta Air Lines with its headquarters in Atlanta, Georgia, has a major fleet and gate position at Hartsfield-Jackson Atlanta International Airport—while also maintaining a large presence at 10 other hubs in the United States, Japan, and France. United Airlines utilizes 10 hubs, all of them international: eight in the continental United States, one in Guam, and one at Narita International Airport in Japan. United's corporate headquarters in Chicago is connected to its large gate complement at O'Hare International Airport.

In a similar vein, the corporate headquarters of Southwest Airlines is at Dallas Love Field, one of 15 airports that Southwest calls its focus cities. JetBlue uses the term *focus city* for the six major and minor hub airports it utilizes and the term *key city* for a range of other destinations.

Key city pairs are an allied concept in airline and airport planning and operations; such a pair may include one or two major hubs. American Airlines, for example, has a business model built around several key city pairs, with JFK New York–London Heathrow the predominant one. Both of these airports are major hubs, serving large international business passenger populations, with origin and final destination points often elsewhere in their host country or in other countries altogether. American Airlines’ partner British Airways, for instance, carries more than 4,000 first class or business class passengers daily between Heathrow and international destinations.

When a hub is used mainly for transfer activity for international travelers, it may be referred to as a transcontinental or “transcon” hub. When the passengers mainly are traveling within a country, however, it will be known as a regional hub.

Savings and Costs

It behooves bodies such as municipal planning organizations to understand the hub and network strategies of airlines when setting out to attract them to their localities. The ability to assemble robust passenger volume is one aspect; another is fuel usage. Airlines and regulating bodies alike are interested in the use of hubs as energy-conserving and cost-controlling solutions. The FAA has sponsored or conducted a wide range of studies to identify performance metrics of air carriers using key city pairs and related hub infrastructure. In its Modernization and Reform Act of 2012 (a part of its “Next-Gen Performance” program), the FAA mandated the tracking of such data as fuel consumption based on average distance flown between key city pairs, a component of the hub system.

The FAA uses its funding capacity as an incentive for municipal and regional planning authorities to make service-area airport decisions with energy conservation and related matters as part of the criteria. By emphasizing the cost-savings aspects as well as the potential pollution-reduction aspects of the hub-and-spoke system, the FAA in this manner



Delta aircraft cluster around Concourse C at Hartsfield-Jackson Atlanta International Airport in Atlanta, Georgia, in April 2012. The airport is a major hub for Delta Air Lines.

adds a practical environmental metric to the market-based calculations that typically drive such decision making.

However, some industry analysts point to growing congestion and delays at hub airports in order to advocate for a pendulum swing back to more point-to-point air travel. These observers point to inefficiencies in time management and failed promise in fuel savings due to overuse of hubs; in other words, the system may have reached the point where it is a victim of its own success. Fuel burned during long taxi and runway delays does indeed undermine the inherent fuel savings of a hub airport operations goal. Many of these analysts, however, see a need to blend the two systems, rather than make an either-or choice between point-to-point and hub-and-spoke.

Among the key drivers of when and where to apply either model will be the availability of appropriately sized aircraft (appropriate to passenger volume and airport fleet capacity), the economic underpinning to support direct flights, and the

continuing evolution of collaborative decision making (CDM) measures among airport administrators and partners, which can support enhanced hub operations even under the pressures of over-capacity demand.

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See Also: Air Traffic Flow Management; Airline Flight Scheduling; Airport Gate Assignment Problems; Airport Planning; Airport Transit Connections; Federal Aviation Administration Reauthorization Act of 2009; International Air Passenger Transport.

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facilities, and any variation is primarily based on configuration of terminals and layout in relation to areas used by airplanes. These include runways, taxiways, and aprons. Additional variation outside the terminal is based on what airport management have decided to do with excess real estate.

Traditionally, airports have made money through fuel sales to airlines, renting hangars to commercial enterprises and private interests, and fulfilling government contracts. In recent years, airports have attempted to widen their profit margins through real estate development. Many of these ventures have included unconventional uses for previously underutilized land. In terms of public relations, the primary task of airport management is to bring positive attention to the airport itself, as opposed to letting the airlines draw all the attention. These efforts usually focus on making airport officials appear like "real" people and making the facility both as personable and pleasant as possible.

The Parts

In the most intuitive terms, the operations of any given airport can be separated into inside operations and outside operations. On the outside of the airport, there are three types of vehicle ways. Aprons are the areas where aircraft park. These areas are also sometimes called ramps, and they typically hold from five to 10 planes. Taxiways are the paths planes use to move from aprons to runways and vice versa. Runways are the paths from which aircraft take off and on which they land. Tasks regarding ground control, traffic patterns, air traffic control, and auxiliary issues must be constantly maintained for proper and safe operation. The air traffic control tower serves to monitor the activity of approaching and departing aircraft as well as make weather observations and collect other data. From that position, ground control staff monitor the activity of aircraft taking off from or landing on runways, as well as those on their way either to take off or to hangars via taxiways.

Traffic patterns on runways, taxiways, and aprons are dictated by various navigational aids and markings. To differentiate between the two major types of vehicle paths, runways are painted with white markings, while taxiways are painted with yellow markings. To assist incoming planes in the dark or in poor weather conditions, runways and taxiways are also marked with color-coded lights;

Airport Operations and Marketing

While many of us do not think outside our own affairs when having to navigate the gauntlet that is an airport, there may be more to airports than you think. They not only employ a great number of people but also host numerous corporate and governmental entities. Within the terminal walls, airports host small commerce ventures (including restaurants and shops), an array of advertisements, and strategically placed security checkpoints. Outside the terminals, there is less variation between

these lights indicate not only the type of strip but also the length of the remaining field. Finally, there are a number of signs that convey important messages to pilots. These signs are as varied as traffic signs on a highway and are just as essential.

There are also a number of auxiliary staff in the ground crew who are critical to the operation of the airport. Ground crew operate fuel trucks for airplanes, service vehicles that perform minor repairs and maintenance, and tugs that help move planes into position between flights. Aircraft rescue and fire-fighting vehicles are always available. For all intents and purposes, these vehicles are identical to their nonairport counterparts. As with the inside of the airport, security personnel are needed to detect and prevent dangerous incidents. Finally, lawn care and other grounds maintenance crews are needed to keep up the outside appearance of the facility.

Inside the terminal, small commerce ventures, art displays and advertisements, security stations, lounges, and other passenger services are key to operations. These activities may take place within multiple terminals or in a single large terminal within one facility. Many airports are broken into several satellite terminals; these buildings are detached from other airport buildings. This is done to allow for the maximum number of plane slots by utilizing all potential area outside the terminal. Another way of utilizing maximum exterior area is through semicircular terminals. This design allows for more planes and decreased travel time within the terminal for passengers on foot.

Small commercial facilities are certainly a critical aspect of airport terminals. These serve many purposes, not the least of which is to distract waiting passengers. These ventures commonly include franchise shops and restaurants, duty free shops, hotel kiosks, and car rental agencies. The interiors of terminals are most often decorated with art displays and advertisements, the majority of which represent revenue drawn for the use of valuable advertising space.

Security teams within airport terminals are equipped to deal with events ranging from mundane passenger disruptions to serious terrorist events. Passenger services are also available; these include but are not limited to providing information to those who need it and transportation for those with special needs. Many airports are also equipped with a range of lounges; these include

those for VIPs (determined in a variety of ways), smoking areas, and simple areas that provide wireless Internet and device-charging stations.

How Airports Make Money

In recent years airports have become less profitable than they were in previous decades. Construction costs have increased. Government loans and grants have decreased, and economic downturns have allowed fewer people to travel by air. Traditionally, revenue sources for airports have included fuel sales, agricultural leases, ramp fees, and government grants. While fuel sales and hangar leases have been highly profitable in the past, they may not be the major profit source for airports in the future. There are many within the aviation industry who put heavy emphasis on the development of real estate assets.

The future of real estate development will likely occur through investment and enhanced property management. It is thought that real estate development and enhancement will provide long-term revenue, but this revenue will not necessarily be airline related. To this point, this has most typically taken the form of leasing to franchises and other interested businesses who seek to have a presence inside the terminal.

There have also been other options for using airport real estate for profit that are more unconventional. Georgia's Hartsfield-Jackson Atlanta International Airport hosts that state's largest blueberry farm on its grounds. San Francisco International Airport and Long Beach Airport both take advantage of solar technology to cover electric costs. Similarly, Boston's Logan International Airport has used wind turbines to offset energy costs and take advantage of environmentally friendly government grants as well as the associated good public relations (PR).

Airport Public Relations

As owners of profit-oriented businesses, the management of airports must put significant efforts into public relations. Marketing experts, including Seth Godin, have identified many ways through which airports can improve their public image. These include but are not limited to tactics that incorporate social media and other elements of Internet culture. The bulk of these solutions can be lumped into improvements in management issues and passenger treatment.

The Internet culture that has developed in the last two decades has made people more connected than they ever have before. Unfortunately, many established public players have been slow to adopt said culture, and airport chief executive officers (CEOs) have often been included among those who have ignored the potential of Internet culture, for both good and bad. In fact, some airports are so late into the game that many facilities have had to compete for their own names on Web sites, Twitter handles, etc. This can range from being inconvenient to damaging, depending on the nature of the individual who claimed the name first. Much of Internet culture challenges hierarchical business models and can be highly unpredictable. For example, social media can be dangerous to the public image of an airport. It used to be that only representatives of large corporations or public figures could be detrimental to the public image of an airport. In this age of social media, one person's bad experience can be disastrous to the public image of an airport, and news of it can spread worldwide in hours. Additionally, the Internet provides nonconventional options to travelers that provide dangerous competition to airports. Through Internet channels, travelers are now able to find nonair travel options, including buses, carpooling, trains, and combinations of travel options, that they may have not been able to find in previous eras.

In addition to being better able to find information about airports and other travel options, potential customers are also highly fragmented in terms of media consumption. In previous eras, it was possible to reach entire demographics or even populations through one or two media outlets. In times past, these were network television or the one or two newspapers that typically dominated metropolitan areas. In contemporary America, people may not only be watching one of a hundred cable channels, they may also be getting their news or entertainment from any number of Internet sources. Furthermore, customers are highly fluid in their preferred modes of entertainment. What is popular today might not be tomorrow. Thus, even if marketers are able to figure out what media their targeted demographic is consuming, this could change in a short period of time.

As far as management issues go, administrators of airports, and the entire air travel experience, have been criticized as being overly sterile, without

joy, and just plain no fun. Critics argue that the current air travel system is riddled with elements that fill travelers with anxiety, and measures must be taken to remove stressful elements from that system. Many of these factors center on the emphasis placed on filling every seat of every plane on every flight. While filling seats may be key in maximizing fuel utilization, the experience of air travelers could be improved if less stress were placed on putting people in seats.

Additionally, the managers of airports, and the airports themselves, need to be more personable. PR experts contend that many of our contemporary airports are completely without character. Critics have also claimed that airports and their management are completely without accountability. When mistakes are made in airports, responsibility is passed from airlines to flight crews to passengers, etc. Regardless of the actual cause of the problem, the management of the facility are often perceived as being to blame for unfortunate incidents. Thus, when airport management takes more responsibility for these problems, they appear to possess greater integrity.

Much can be done to improve the perceived image of airport management by treating passengers better. By extending personalized service to passengers, the experience is humanized and perceptions will improve. A prime area for improvement in this regard is customer service; if customers' problems are addressed in a polite and caring manner, they will not only be less likely to report negative experiences to potential future passengers but also may actually report positive experiences. Finally, and potentially of greatest impact, if airports offered higher quality food selections for more affordable prices, great strides could be made in public relations. That is not to say that airports should eliminate their fast food options or high-end dining for those who wish to have these experiences. However, when people are tired and stressed from travel, many middle-class passengers want an affordable meal of higher quality than fast food.

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See Also: Airline Industry; Airline Marketing; Airport Hubs; Economic Development; Economics of Air Travel; Transportation, Economics of.

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Airport Parking and Ground Transportation

At airports the American aviation system intersects with other modes of transportation, including automobiles, buses, and trains. Airports are places where federal responsibility for managing and regulating air traffic operations coincides with state and local governments that own and operate most airports. Authorized in 2003 as part of the Vision 100—Century of Aviation Reauthorization Act of the Federal Aviation Administration (FAA), the Airport Cooperative Research Program (ACRP) helps the airline industry to develop innovative solutions to efficiently plan airport operations, including airport parking and ground transportation.

According to the ACRP, operators of airport parking facilities focus on customer service more than do publicly owned facilities. Airports present a passenger's first or last impression of a community, and airport parking facilities present first or last impression of the local airport. Airport operators work to give customers a higher level of service than

other public parking facilities, so airports often are the first to implement innovative parking services and technologies.

The FAA requires that commercial-service airports be as financially self-sustaining as possible. To meet this requirement, airport operators rely on revenues from airlines, including landing fees, terminal rents, and other charges. They also depend on concessionaries and other tenants, such as rental car companies, ground transportation providers, and public parking facilities.

Airport managers frequently compare their own airports with other airports of similar size. Size is defined in terms of the number of annual originating and destination airline passengers, as they are the customers who use parking facilities. Most medium- or small-hub airports serve few connecting passengers, so comparable airports can be identified using the number of enplaned or deplaned passengers. Many large-hub airports serve as hubs for a major airline, garnering them a large number of connecting passengers.

Public Parking Revenues

Commercial service airports usually provide over 1,000 parking spaces and several large-hub airports provide over 15,000 public spaces. These large parking facilities are necessary because over 70 percent of all passengers travel in private vehicles and some of them park at the airport for several days. Public parking is usually the single largest revenue source at airports in the United States, providing approximately 25 percent of all airport revenues and more than 40 percent of nonairline revenues. Annual parking revenues often total over \$10 million at small-hub airports and over \$100 million at the largest airports.

Surplus revenues from public parking often provide funds to support other airport operations that make no income or require subsidies. Surplus parking revenues also represent the single largest source of debt-free cash flow to fund airport capital improvements. Parking revenues are shared with the airlines at some airports, which helps maintain existing service and attract new airline service.

Airport managers frequently cite three airport parking goals. They aspire to provide a high level of customer service for the traveling public and employees. They strive to improve operational efficiency by reducing the costs of parking operations



A Skylink automated people mover station at Dallas/Fort Worth International Airport in Texas. Only about 2 to 5 percent of U.S. air travelers take rail transport to and from airports, compared to 20 to 30 percent at many European and Asian airports.

while maintaining or improving customer service and safety, and they work to enhance revenues and net parking revenues while achieving their other goals. Some airport operators forgo possible revenues to provide improved customer service by providing a high proportion of close, covered parking spaces. Other airport operators choose to defer construction of structured parking and expand surface surfaces within walking distances of the terminal instead.

Baselining and Benchmarking

Airport owners need to develop a baseline to compare parking metrics. The airport operator can collect and analyze “before” data by selecting a

time period to analyze existing data or to collect new data. Progress can be gauged by measuring improvements over a fixed time period. Progress can also be measured by evaluating performance compared to a future target. Some of the more commonly used parking-related metrics to monitor and track parking revenues are facility utilization, customer service, operations, and other aspects of public parking.

In the field of airport parking, benchmarking is the operation of comparing the fees, space numbers, types of products and services, revenues, operational practices, and other areas of an airport’s parking operations with those at other airports. Benchmarking helps airport operators determine how their parking operations rank or compare to such specific measures as parking rates or spaces. Benchmarking can also be used to increase management’s awareness of the operations and facilities at other airports.

The Seven Planning Steps

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) establishes guidelines for airport ground transportation, and the Research and Innovative Technology Administration (RITA) of the U.S. Department of Transportation explains seven steps in a government document called *Airport Ground Access Planning Guide*.

The first step is defining the problem and pinpointing the policy issues that the airport faces, because its unique characteristics and setting define its performance standards. For example, an airport in an air quality nonattainment area must lower its total vehicle miles of travel with airport access to reduce vehicle emissions.

The second step is fully understanding the policy issues and establishing performance measures to use in the monitoring and evaluation program. Airport ground transportation planning issues include quality of traffic flow on the access roads near and on the airport. The number of choices the passenger has between taxi, shared ride van, scheduled bus, limousine, or rail service to reach his/her ultimate destination is important. It is equally important to determine the percentage of the region served by shared ride services, the percent of passengers arriving by other than private vehicle or single ride taxi, and the percentage of passengers arriving in a vehicle with low emissions propulsion.

The third step is collecting the data that documents access conditions and level of performance. Airport access patterns can be understood by examining multiple data sources, including periodic ground access surveys, ridership and revenue data, and time, cost capacity, and usage. The Port Authority of New York and New Jersey has monitored ground access patterns to JFK, LaGuardia, and Newark airports for several decades and has collected valuable data.

The fourth step is understanding existing and future conditions and system performance. San Francisco International Airport is doing pioneer work modeling existing conditions and patterns in ground access, experimenting with parking prices, and evaluating policies for managing and regulating shared ride van operators.

Developing and evaluating statewide and local strategies and actions that improve the intermodal efficiency for the movement of people and goods is the fifth step. Options considered should include a full range of possible solutions beyond highway and rail transportation back and forth to airports. In San Francisco, the private sector developed an extensive shared ride van system with water transportation being discussed. Water transportation services are part of the overall strategies in Boston and New York.

Assessing the effectiveness of alternative strategies and actions and selecting cost-effective actions is the sixth step. The evaluation of alternative strategies can extend beyond analysis of vehicle flows and include such concepts as people and goods mobility, and accessibility to various activities and land uses. In Salt Lake City, analysis alternatives focused on dealing with a serious air quality, non-attainment situation.

The seventh step is implementing feedback using the established performance measures. Strategies implemented are case based. Salt Lake City had an air quality issue and selected a strategy that addressed the levels of pollution from shuttle vans, instead of reducing travel time. Salt Lake City and Washington National Airports provide space for everyone on airport rental car operations in a garage near the terminal. The Massachusetts Port Authority has monitored the air quality implications of its actions, ranging from parking pricing policies to the monthly variations in ridership on its express bus services. The Port Authority conducts

comprehensive ground access surveys every five years to track changes in travel behavior.

Future Planning

With cars, taxis, shuttles, and limousines crowding their roads, a growing number of airports are building or are planning to build a rail link connecting passengers from the terminals to regional metro-rail systems. Europe and Asia have long had airport rail links. In many European and Asian airports, 20 percent to 30 percent of travelers go to and from the airport using rail, but ridership in the United States typically ranges from 2 percent to 5 percent.

Just a few of the largest U.S. airports have rail service dropping passengers within walking distance of the terminals. Airports with rail connections include Atlanta, Chicago O'Hare, New York John F. Kennedy (JFK), San Francisco, Newark, Minneapolis, Boston, Philadelphia, Washington, D.C., and in December 2012, service was extended to the edge of the Dallas/Fort Worth International Airport.

Airports and airport managers are learning that building more parking lots and enlarging roadways are planning practices from the past and that airports of the future will have to embrace the green movement by budgeting more money for programs that reduce their carbon footprint. More federal funding sources for airport rail are impacting airport ground transportation planning.

Airports wanting to build a rail connection can add to existing systems. Seattle's Sound Transit initiative passed in the late 1990s to build a regional light rail system. A 16-mile line, the Central Link, runs between downtown Seattle and Sea-Tac Airport. Oakland Airport is constructing a link to the nearby BART system.

In Salt Lake City, Utah, the Airport TRAX Line is a six-mile rail line extending the existing TRAX system from Arena Station to the Salt Lake City International airport.

Airports and airport planners are considering People-Mover Rail as another design of the future. Some airports have a nearby metro station just out of walking distance, and to close the gap they are building automated people-mover trains. People-movers typically run within airport grounds, so airport authorities can tap funding sources available only for airport projects. Phoenix Sky Harbor International Airport used passenger facility charges to partially

fund its Sky Train, a people-mover that connects to a nearby light rail station. One airport station contains an enclosed moving walkway that takes travelers directly to the terminals. Phoenix Sky Harbor convinced the Federal Aviation Administration to allow it to use the passenger facility charge, a fee added to air tickets, to partially fund its rail project. The Miami International Airport Mover can transport more than 3,000 passengers an hour directly between the airport and the Rental Car Center's customer service lobby. Passengers simply leave their concourse, take elevators to the third-level moving walkway, and are quickly connected to the MIA Mover.

The MIA Mover replaces the Rental Car Center shuttle bus service, eliminating about 1,400 shuttle bus trips a day, and reduces carbon emissions from the airport's roadways by 30 percent.

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See Also: Airport Hubs; Airport Passenger Terminals; Airport Transit Connections; Airports, Environmental Issues and.

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Airport Passenger Terminals

The first facilities that can be considered airport terminals were built in the early 1920s for the use of airmail. These facilities are now used for the efficient transport of goods and passengers between communities, but they are also an economic engine for the region as they generate employment and are a source of revenue. Airport passenger terminals are one of the principal elements of infrastructure cost at the airport. Several terminals that are architectural masterpieces have not been able to perform the expected functions. Three main basic functions can be attributed to terminals: change of mode (air-land), processing, and change of movement type (holding spaces-movement).

While most terminals are utilitarian in design, some stand out, either because of their architecture or the variety of additional services offered, and are valued for their aesthetic and social function. Several terminals are considered architectural masterpieces such as the the King Abdulaziz International Airport in Jeddah, Saudi Arabia; the Beijing Capital International Airport in China; South Korea's Incheon, International Airport; Lyon-Saint Exupéry Airport in Lyon, France; or Spain's Madrid-Barajas Airport.

An early example of notable terminal design was the Pan Am Worldport at JFK International in New York, opened in 1960 and rebranded as the Worldport in 1971. Used as the terminal for Pan American World Airways, the Worldport was designed by the architectural firm Ives, Turano, and Gardner, with Walther Prokosh of Tippetts-Abbett-McCarthy-Stratton, and included an enormous "flying saucer" roof, the edges of which extended far beyond the terminal's outermost columns. The design of the terminal advertised the modernity of Pan Am, and indeed of air travel itself, tying in to Pan Am's jet age/space age brand identity.

The general trend of airport terminal design since the 1970s has been to tailor them specifically

to their location, both in terms of local transportation needs and aesthetic choices. The exterior of Denver International Airport's Jeppesen Terminal, for instance, was designed by Fentress Bradburn Architects with a Teflon-coated fiberglass roof that resembles the snow-covered peaks of the Rocky Mountains. Inside, the terminal (opened in 1995) hosts both permanent and temporary art exhibits, including Luis Jiminez's sculpture *Mustang*. The terminal is connected to Concourse A by a pedestrian bridge that allows travelers to watch planes taxi below them, along with a view of the Rocky Mountains. Similarly, in Morocco, the Marrakech-Menara International Airport's two passenger terminals combine elements of both modern and traditional Islamic architecture, with the heavy use of glass and marble in the interior evoking memories of much older buildings. In China, Beijing Capital Airport's Terminal 3 (opened in 2008 in time for the Olympics) was designed by Norman Foster, an architect who is also a recreational pilot. The terminal's design is intended to evoke the experience of flight: it is vast (2 miles long), with a roof that rises upward as though floating, and angled cuts in the canopy that result in sunlight shining through. The arrival area of the terminal was designed with input from a Feng Shui expert.

Passenger terminals are the first point of contact for the arriving passenger. Airports are usually subsidized by public entity, so their terminals are highly influenced by political and economic developments. They are important elements of the air transport system as interchange nodes between land and air transport systems.

Passenger terminals play an important role as social connectors and economic engine. Their main characteristics and design depend on factors such as the expected number of passengers and the kind of routes being offered. However, there are social aspects influencing terminals, and the type of passengers is one of them. Many passengers are not interested in extra services if they represent an additional cost. For instance, waiting areas for low-cost airlines can be less comfortable and smaller when compared to the ones provided for the usual passengers. Moreover, terminals have to conciliate the needs of transfer passengers, who need fast and easy-to-find connections, as well as arriving passengers, who are interested in easy connections with land transport, airlines, ground-handling, and retail.



A vast passenger terminal at Bangkok's Suvarnabhumi International Airport in 2007. Such terminals facilitate three main functions: change of mode, processing, and change of movement type, as well as other social functions.

Terminals are usually managed by a combination of public and private management, which creates a unique political role. There are important differences in national attitudes and values that influence local decisions regarding terminals. Important national considerations should be taken into account and consequently will determine the terminal's planning. For most passengers, flying can be stressful, so terminals should ideally be a place to relax and spend time. Shops represent the most common solution for spending time, and some terminals are very similar to shopping malls. For example, in Zurich, the terminal provides such a variety of shops that local residents go there just for shopping.

This transformation of the terminal into more than a connection node between air and land is a result of social changes through time. Nowadays, terminal users look for additional services, such as casinos, cinemas, fitness centers, and play areas for children. Terminals are changing airports, which are gradually becoming small cities in their own right with a great variety of facilities and services, such as in Dallas/Forth Worth in the United States. Moreover, a terminal that provides good facilities for passengers, such

as retail stores and business conference rooms, can generate substantial revenues. Passengers' airport choice depends on the services available, so in general, more services mean more passengers.

The added value generated by an airport can also be perceived in local real estate values, which increase with a relative proximity to this facility. However, being too close to the airport can produce the opposite effect because of the noise.

A terminal's configuration is influenced by the urban characteristics of its surroundings: combined passenger buildings for several airlines are common in smaller communities, and separate buildings are usual in larger metropolitan areas. This might seem a contradiction since larger urban areas have less available space, but these areas need to serve more passengers. Four types of configuration can be found: finger piers, satellites, midfield, and linear.

Nevertheless, terminals are also highly influenced by policy. Security, land planning, and environmental policies are perhaps the most significant. Concerning environmental policies, Frankfurt Airport Terminal 2 uses rainwater for air conditioning and lavatories. Urban planning policies are important to assure the correct integration of the airport with the city and to minimize the impact on the landscape. In Bristol in the United Kingdom, the terminal height was limited to one level on the airside to minimize its impact on the landscape. Moreover, terminals have to be part of a city. As such, there should be reliable land transport to assure its access to everyone.

Regarding security, policy directives often emerge as a form of protection against terrorist attacks. On December 23, 1988, a bomb explosion on B747 Pan Am Flight 103 over Lockerbie, Scotland, resulted in changes to passenger terminals to physically separate arriving from departing passengers as well as the installation of explosives detection equipment. As a result of the 9/11 attack, for instance, only passengers with valid boarding passes are allowed beyond security points.

Despite looking like typical transport infrastructure, passenger terminals are more complex. They generate important social and economic benefits for the community. Moreover, their functions and configuration are more sensitive to social aspects and policy than other transport facilities.

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See Also: Air Passenger Carriers; Airline Industry; Airport Administration; Airport Hubs; International Air Passenger Transport.

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Airport Planning

Airport planning is a multidisciplinary field that encompasses rural, urban, local, and regional land use policies; business development and tax issues; environmental, safety, and national security factors; public and private transportation processes; construction engineering contracting and negotiations; labor relations and regulations; comprehension of federal airspace and aviation rules and practices; and advances and challenges in technology.

The decisions made in airport planning frequently impact the local and regional physical environment and the business and community infrastructure, and they can affect local and regional economies by either stimulating or obstructing related forms of development.

Capacity and Systems

Airport planning typically begins with studies of local and regional capacity projections that cover cargo and passenger volume as well as overarching economic trends and land development issues in a given region. Attention must also be given from the earliest planning stages to funding requirements and sources, as these involve often lengthy hearings, negotiations, and legislation at local, state, regional, national, and sometimes international levels.

Airport planning includes not only the design and specification of new airport facilities but also the structure and function of the airport administration

and operations staffs, facilities, technology, and their associated rules and regulations.

Ultimately, airport planning must take into consideration the National Airspace System (NAS) and the National Plan of Integrated Airport Systems (NPIAS), which were developed by the Federal Aviation Administration (FAA) to standardize and rationalize the infrastructure of air travel and transport in the United States. Some 3,400 airports across the country are categorized by the NPIAS as either (1) primary airports, (2) commercial service airports, (3) general aviation airports, or (4) reliever airports. The standards that apply to each of these categories must be considered during the airport planning process.

In addition to aircraft handling, as well as airline passenger and air cargo support, the planning process for an airport also must analyze the surface transportation links, access, and intermodal structure as part of a comprehensive consideration of all challenges and potential of the airport and its surrounding area.

Congestion and Coordination

The prevailing projections for increasing congestion in air traffic mean that airport planners are well advised to cooperate and coordinate to increasing degrees on a regional basis. In the United States, for example, the regional airport systems planning (RASP) concept is the approach developed and favored by the FAA Office of Airports. The FAA in the first decade of the 21st century made available some \$20 million in planning funds to encourage better regional planning practices by nine of the 10 most capacity-constrained metropolitan airports, as defined by projections to 2025.

The issue of air traffic congestion and a regional approach to solutions is not universally accepted, however. This is due in part to the fact that airport authorities sometimes have different priorities from those of federal, state, or local governments and to the fact that the FAA is mandated to make funding decisions on the basis of national security, which often is not a primary concern in the capital investment decisions of airports themselves. Some major airports, for instance, may elect in their planning to not divert traffic to alternate regional airports as a matter of strategic business and financial policy. This can undermine application of the RASP approach in a given region.

It is largely during the lobbying campaigns conducted by airport developers and their associated elected officials for federal transportation funding that the RASP priorities can be emphasized. However, the issue is further complicated by the fact that more than three-quarters of the metropolitan planning organizations in the United States lack the mandated authority to conduct aviation planning on a regional basis. Many such planning bodies are not engaged in regional revenue-sharing models that would specifically provide motivation for the necessary changes in mandates.

Flexible or Dynamic Approach

In contemporary airport planning, much emphasis is given to flexibility in the design of airfield layout and operational systems, with more planners favoring a dynamic approach that maximizes the ability of administrators to adapt and alter future designs and build-out in response to changing economic, physical, social, and technological parameters. A focus on integrating the airport design and operations into the evolving plans of its commercial, private, and public-sector clients is also of increasing importance. Many of these factors can be studied via computer-aided simulations, and the results can be applied as the planning proceeds.

As with planning in related fields—business, military, institutional—there are valid reasons to approach airport planning with a “Plan B” always at hand. Future economic growth patterns, regional competitive issues in a largely deregulated industry, changing levels of local political support or conflict, new or newly enforced legal mandates, and other unpredictable and uncontrollable external forces can all turn primary planning on its head. These unforeseen developments each come with their own costs, which can drastically undermine what were otherwise intelligently devised budgets and plans.

Operational costs change over time, and the sustainability of these costs must be considered based on service-demand levels and the airport’s desired minimum standards of service.

Delivery of desired service levels over time calls for sharply defined understanding of the local and regional dynamics of any airport. While air passenger volume is projected to double over a 20- to 25-year period (as it has in the most recent such periods), this traffic measure is a global one. Even

while this type of projection has mostly remained accurate as a rough estimate in the United States, for example, there exist many variations across the country. Markets elsewhere in the world have shown even greater variation, for example, between airports sited close to the fastest growing cities in Asian countries such as China and India, and other more stagnant-growth cities within the same countries.

The uneven distribution of passenger volume and the difficulty in predicting local and regional economic shifts as much as two or three decades into the future, puts a high value on the ability to shift build-out and systems integration while maintaining standards and controlling costs as planning proceeds. Airport planning as a discipline now has an engrained “doubling” approach that must be tempered with the reality of changes in economic, environmental, and related social and political pressures that can either spur or hinder expected expansion or can alter priorities due to new local and regional transportation developments such as rail, bus, telecommuting, and other alternatives to air transport.

Fortunately, there is a wealth of software simulation products that can help planners maintain flexibility as they work to project airport expansion and to account for repair, upgrades, and maintenance during variously assumed periods of rapid, flat, or negative growth.

Additional consideration must be given to the expected changes in aircraft activity level, composed of both aircraft operations (takeoffs, landings, touch-and-go) and based aircraft (general aviation “resident” vehicles, as opposed to major carrier aircraft). In some cases, airport planners must incorporate a majority-in-interest approach to aspects of their plans. This means that those air carriers providing the majority of traffic at the airport—and who will be the most affected by rate and fee increases—must be given advise and consent rights to review plans for significant capital investments that are likely to add upward pressure on the airport’s long-term and operational cost structure.

Infrastructure Parameters

At the most basic level, airport planning must account for both the airside or airfield domain as well as the landside or terminal building and

ground transport domain. Airside factors such as runway lengths and orientation, apron and taxiway layout and navigation aids, pushback maneuver space and related aircraft handling arrangements, roadway and building obstruction clearances, jet-blast and noise mitigation, and the alignment of cargo facilities, passenger terminals, redundant safety and fire suppression equipment, and security and maintenance buildings will all be taken into consideration. Integration of all ground service and support service vehicles must be designed into this layout, along with accommodation for various sizes and configurations of commercial fleets and private aircraft. Air traffic control in particular is a section of the airside planning that must be designed and conducted to meet the certification requirements for commercial air service operations standards.

Working with the range of ancillary service providers—food vendors, retail and financial outlets, telecommunications, ground transport rental firms, and the hospitality sector, as well as medical support and security staffs—is part of the people-centered planning process of landside operations. Designing airports to accommodate disabled and special-needs individuals and their health aids, family, and helpers is an essential part of this matrix. Retrofitting existing airports and designing new airports to comply with enhanced national security mandates adds still another layer of planning that particularly affects the landside.

Duty cycles, repair and maintenance schedules, and replacement timetables for pavement and other structural and building components are essentials of planning, as are fuel costs, climate-change dynamics as they apply to population movement trends, and related air carrier issues. These entail factoring in requirements for personnel, materials, supplies and supplier negotiations, and technology upgrades and the associated training needs. Each factor comes with an associated capital investment or operational expense vector.

Administrative staffing and development costs are layered over all of these needs, both airside and landside, and must be continually adjusted to reflect any alterations in plan fundamentals of demand and service level. Only when developed together in a comprehensive model through the use of reliable and contemporary simulation systems can an airport plan be considered capable of producing a

realistic set of assumptions and a coordinated set of budgets tailored to those assumptions.

Environmental Factors

Another vital component of airport planning—and one that has consistently become more pronounced in terms of potential impacts to the structure and cost of layout, operations, and administration—is the environmental component. This category includes such major factors as air, soil, and water quality and protection; wildlife and endangered species considerations; and noise pollution and mitigation. Each of these factors is subject to a range of confirmed, established code and enforcement precedent; each can also be subject to a variety of unpredictable legal challenges of a civil nature, as local and regional constituents learn about developing airport plans and respond with questions about or challenges to the planners' assumptions regarding such impacts.

Beyond such immediate impacts as soil compaction, ground cover disruption, threats to water quality, and air pollution, local and regional stakeholders in many cases are increasingly likely to draw the airport planners into broader discussions of how the airport's activities will be integrated with—or conflict with—other ongoing, nonaviation transportation plans in the area that may involve modes and developments that are either unrelated (except by proximity) or those that are suitable for direct integration with the plans of the airport's development. Not only will the natural environment be considered in the planning, but such factors as the protection of historic and cultural sites must also be covered.

An environmental impact review (EIR) and environmental impact statement (EIS) are the essential documents that need to be part of any airport planning process. The EIR is a general outline of the potential environmental surrounds, projected impacts, and challenges; the EIS is a more detailed examination that must also include planned mitigation procedures and strategies that will satisfy legal, political, and social requirements. A shorter version of the EIS known as an environmental assessment (EA) can be used in cases where likely impacts to the area can be reasonably expected to be less significant.

Environmental plans and documents, to pass muster with the various federal and local regulatory

agencies, in general must include both mitigation strategies and financial plans to cover the costs associated with putting these strategies into action. An acceptable EA or EIS must list and explain alternatives to the major features of the overall airport plan, so that its eventual environmental impact and mitigation can be assessed within the context of other options to serve the transportation needs of the taxpayers and other constituents.

Today's Tools and Tasks

If flexibility in predictions and response are the keys to successful airport planning, then contemporary planners enjoy an arsenal of technological tools that have been enhanced by several generations of real-world trial and error, as well as contributions from computer simulation experts and aviation's array of professional societies. Decision and options analysis, variable load modeling of factors such as peak-hour flows and queues, data validation, and risk forecasting are among the standard applications that have been shaped into modern airport planning software, guide materials, and practices.

Facing the planner today are projects that span the globe and range in size from small local facilities in high-amenity rural areas to the major new airports in booming metropolitan zones. Reconstruction projects are among the most accessible and rewarding to the up-and-coming airport planner, as the timetables are often compressed and the learning curves steeper. Examples of reconstruction include airline terminal facility makeover, addition of automated people-mover systems, new railroad (including monorail) connections, international passenger customs and security handling facilities, runway reconfigurations, and general passenger building expansion.

Software companies that provide airport planning tools to the industry are cognizant of the need to stay competitive and improve their products by incorporating such developments as newly promulgated FAA advisories, debt financing options from new types of securitization sources and newly initiated taxes and fees, changes in risk acceptance behavior by air carriers, macro-economic trends, and the availability of new construction techniques and more durable materials.

Software packages typically offer modules to assess needs and costs for construction, operations,

and administration. These can be tuned to different scenarios depending on the applications and priorities preferred by management and in light of variables that emanate from outside constituents such as metropolitan and regional elected bodies, allied industries, real estate interests, civic and social interest groups, and the airport-neighbor population.

In preparation for acquiring airport planning knowledge, or in ongoing professional education to update such skills, there are numerous vocational and higher education sources and channels to consider. One validation of a course of study is whether it is offered through the National Center of Excellence for Aviation Operations Research (NEXTOR). The FAA sponsors NEXTOR through its Office of Technology Development and Operations Planning; the program is an alliance with various academic and aviation industry partners. The industry partners are drawn from both the public sector (for example, California Department of Transportation, Maryland Aviation Administration, Massachusetts Port Authority, etc.) and private industry (for example, Boeing, Federal Express, Northrop Grumman Corporation, etc.). Academic core partners as of 2012 included eight major public universities in the United States.

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See Also: Airport Hubs; Airport Operations and Marketing ; Airport Security; Airport Transit Connections; Airports, Environmental Impact of; Federal Aviation Administration Reauthorization Act of 2009; National Airspace System; Regional Transportation Planning; Section 504 Regulations on Accessibility.

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Airport Security

The Transportation Security Administration (TSA) was formed in November 2001 in response to the September 11, 2001, terrorist attacks, in which airplanes were flown into buildings in New York and Washington, D.C. TSA's mission is to conduct security screening of air passengers and luggage. Originally part of the U.S. Department of Transportation, the TSA became part of the Department of Homeland Security on March 9, 2003. Today the TSA faces the dual challenge of increased airline passenger travel and the need to improve the efficiency and effectiveness of screening.

Policy makers and aviation security planners work continually to incorporate into established systems and procedures new technologies that do a better job of detecting security threats. Challenges they face in their efforts to maintain and improve screening functions include optimizing inline explosives detection, streamlining systems for checked baggage, improving the capability to detect explosives at passenger checkpoints, developing strategic plans to improve screening

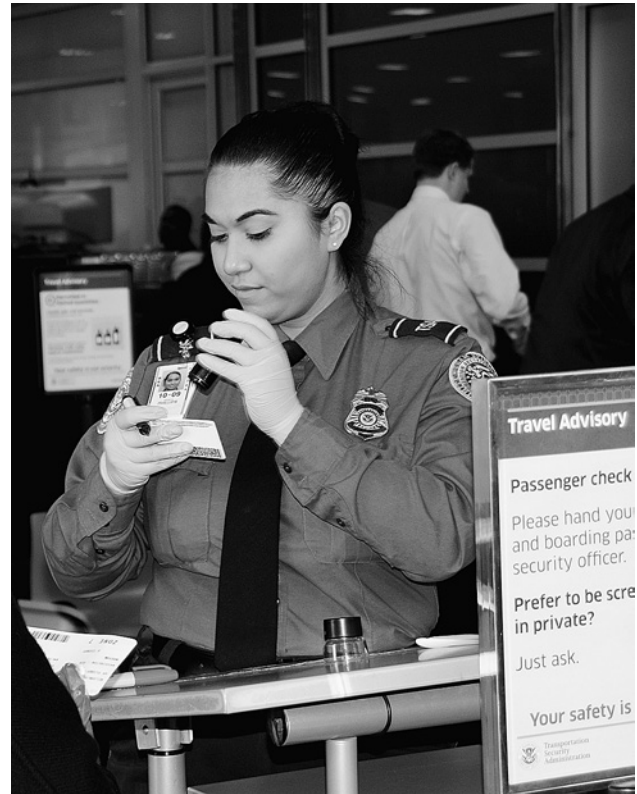
technology, more fully integrating trusted travelers programs, stopping cyberterrorism, maintaining the No Fly List, and possibly arming TSA workers.

Hijackings, bombings, the terrorist attacks of September 11, 2001, when hijacked airplanes were flown into buildings, and universal searches of passengers have permanently altered the nature of air travel worldwide and in the United States. On September 6, 1970, Palestinians hijacked four airplanes, two of which were American, and took 310 hostages. They transferred the majority of hostages to Amman, Jordan, and freed them on September 11, 1970. On September 12, they blew up the empty planes. Responding to this threat, President Richard Nixon placed sky marshals on designated flights to discourage hijackers.

Dan (D. B.) Cooper drew more attention to the problem of airport security when on November 24, 1971, he handed a note to a flight attendant shortly after Northwest flight 305 took off from Portland, Oregon, bound for Seattle, Washington. In the note he demanded a \$200,000 ransom or threatened to blow up the plane with explosives in his bag. Northwest handed over the money, Cooper lowered the stairs at the back of the plane, and he, along with his ransom money, parachuted into infinity. After D. B. Cooper's escape, airplane makers created a Cooper Vane, which made lowering rear stairs during the flight impossible.

Despite President Nixon and perhaps because of D. B. Cooper, the hijackings continued. In December 1972, the Federal Aviation Administration (FAA) mandated that airlines search all passengers and their bags beginning in 1973. Airport security directors installed metal detectors called magnetometers in their airports. It took some time, technology, and court cases for people to become accustomed to magnetometers and for their use to be widespread. Consumer advocates worried about metal detectors and radiation, but studies proved that they gave off scant radiation.

People took the FAA to court, claiming that magnetometers violated the Fourth Amendment, which protects against illegal searches and seizures. The courts ruled that magnetometers were covered by the Fourth Amendment, but they were acceptable as long as their searches were applied universally and limited to looking for weapons and explosives.



A transportation security officer from the Transportation Security Administration (TSA) reviewing passenger identification at a security checkpoint on July 18, 2012.

Baggage Checking

Standards for checked baggage screening were first put into place after plastic explosives hidden in a checked bag blew up Pan Am flight 103 over Lockerbie, Scotland, in December 1988. Since 1997, the FAA has used CAT scans (computed axial tomography imaging) to check bags and baggage at most of America's major airports, including San Francisco International and Hartsfield-Jackson Atlanta International. The CAT scanner is a hollow tube that surrounds a bag and then revolves slowly around it, gathering and recording data by bombarding the bag with X-rays.

Since CAT scanners are slower than other types of baggage scanning systems, security personnel check only the bags that the computer designates as suspicious. An unusual circumstance showing up when a passenger makes reservations or checks in is usually what alerts the computer to flag a piece of luggage. For example, if a passenger buys a one-way ticket and pays cash, the computer responds with a

flag and the passenger's checked bags are immediately sent through the CAT scanner.

Screening passenger baggage is controversial. TSA's policies and personnel have been under scrutiny since the inception of TSA in 2001. The TSA's Office of Investigations and the Homeland Security inspector general's office routinely test the effectiveness of airport screening processes, and some investigations have revealed that actions of some TSA employees often neutralize or erase the safety impact of stringent baggage checking. A 2006 report found several instances of improper collaboration between airport security personnel and TSA officials to warn screeners about undercover tests. A report on undercover operations at Newark Liberty International Airport in October 2006 revealed that screeners had failed 20 of 22 undercover security tests and had missed numerous guns and bombs.

In July 2007, the *Times Union* of Albany, New York, reported that TSA screeners at Albany International Airport failed multiple security tests conducted by the TSA, including missing a fake bomb. In a December 2010 story about a man accidentally taking a forgotten gun through airport security, ABC News Houston said that "the failure rate approaches 70 percent at some major airports." In June 2011, TSA fired 36 Honolulu International Airport screeners for consistently not inspecting bags.

A Government Accountability Office report dated July 30, 2013, citing a 26 percent increase in offenses among TSA employees between 2010 and 2012, seemed to support the public perception and TSA evidence that not all TSA workers are competent or honest. The report cataloged 9,622 offenses by TSA employees; complaints regarding the employees' ethics, integrity, and appearance were recorded, as were 56 cases of theft. Between TSA's inception in 2001 and 2011, approximately 500 screeners (out of 60,000 baggage and passenger screeners) were fired or suspended for stealing from passenger luggage. JFK, LaGuardia, and Newark airports were among the most affected.

Critics have also complained that TSA does not respond properly to thefts and does not reimburse passengers for stolen goods. Passengers who used the Hartsfield-Jackson Atlanta International Airport in 2011 and 2012 reported that the TSA lost or damaged property worth \$300,000 and that the TSA reimbursed only \$35,000 of the claims.

At Jacksonville International Airport, passengers reported \$22,000 worth of goods missing or damaged over a period of 15 months, and the TSA reimbursed only \$800.

The TSA continually evaluates multiple passenger and baggage screening initiatives, including tests of new passenger checkpoint layouts and field testing of next-generation screening technologies. These technologies include machines that detect explosives and chemical traces of explosives, whole-body imaging systems, and advanced technology X-ray capabilities.

Full-Body Image Scanners

Beginning in 2007, governments in many countries, including the United States, began replacing metal detectors with full-body scanners at airports and train stations. In 1992, Steven W. Smith developed the first full-body security scanner called the Secure 1000. He sold the scanner and its patents to Rapiscan Systems, which manufactures and sells the scanner. By November 20, 2010, the TSA reported at least 385 full-body scanners were in use at 68 U.S. airports. The government planned to install 1,000 full-body scanners by the end of 2011, and the government also suggested that it would install full-body scanners in train stations and subways.

A full-body scanner used for security purposes can detect items on a fully clothed person's body without making physical contact. Depending on the technology, the operator can see an alternate wavelength image of a person's naked body or a simple cartoon cutout of the person revealing any suspicious objects. For privacy and security reasons, other passengers generally cannot see the display, and in some places the display is located in a separate room where the operator cannot see the face of the screened person. Full-body scanners can detect nonmetal objects as well.

Taking about 15 seconds, full-body scans are quicker than a strip search, and people do not have to remove their clothes. The analyst sits in a different room and is not supposed to see the person being scanned but is in contact with other security personnel who can stop the scanned person if anything suspicious appears on the scan.

Individuals still have the right to opt out of the scanner and choose a pat-down if the individual is uncomfortable going through the scanner. Individuals also have the right to be patted down in a

private room and have the pat-down witnessed by a person of their choosing.

Sometimes security personnel do a clothes-on pat-down instead of a full-body scan, and a pat-down is often used as a follow-up when a scan detects a suspicious object. In other airports, a full-body scan is mandatory, and if a passenger refuses to be scanned, the airline can bar the passenger from the flight.

Federal law in the United States stipulated that after June 2013, all full-body scanners were required to use Automated Target Recognition software, replacing the picture of a nude body with an image looking more like an avatar or a cartoon. One side effect of the ruling is that the Transportation Security Administration will remove all backscatter X-ray machines since Rapiscan, the manufacturer of the machine, would not be able to meet the deadline.

Passenger Screening and Privacy Concerns

Passenger screenings in airports have taken a central position since four of the five hijackers who flew airplanes into the Pentagon were stopped at Washington Dulles International Airport on the morning of September 11, 2001. They were taken aside after setting off metal detectors but were allowed to continue onto their flight.

Full-body scanners have raised privacy concerns since they were introduced in airports in 2007. Another attempted bombing attack heightened the controversy swirling around the effectiveness of full-body scanners. On December 25, 2009, 23-year-old Umar Farouk Abdulmutallab, a Nigerian who had concealed plastic explosives in his underwear, attempted to detonate them on an international passenger flight from Amsterdam to Detroit Metropolitan Wayne County Airport in Romulus, Michigan. There were 290 people aboard the Northwest Airlines Airbus A30-300, but fortunately Abdulmutallab did not properly detonate the explosives. A Dutch passenger, Jasper Schuringa, restrained him and, with the aid of others, put out the fire while the pilot safely landed the plane.

A Gallup poll taken immediately after the 2009 Christmas Day bombing attempt found that 78 percent of American Airlines travelers approved of body scanners, and 20 percent disapproved. Fifty-one percent of those surveyed said that they would

be uncomfortable with full-body scans, while 48 percent said the idea of full-body scans would not make them uncomfortable. Some people disagreeing with full-body scans said that full-body scanners would not be able to detect the explosives that the “underwear bomber” used in the bombing attempt.

The full-body scanners remained controversial despite the Christmas Day bombing attempt. A Consumerist Web site poll on November 23, 2010, showed that 59.41 percent of people said that they would not fly because of the scan requirements. On November 2, 2010, an MSNBC poll of 8,500 online readers indicated that 84.1 percent believed the scanner would not increase travel safely. On November 15, a CBS telephone poll of 1,137 people showed that 81 percent of those polled approved of TSA’s use of full-body scans.

Privacy and the disposition and legality of the images are major issues associated with full-body scans. Advocates of the full-body scan contend that the head is excluded from the scan and the images are instantly erased, though there are cases where images have been stored and leaked online. Some passengers have objected to having pictures of their naked bodies displayed to screening agents or recorded by the government. Critics call the imaging virtual strip searches without probable cause and they claim the images are illegal and violate basic human rights.

Full-body scanning technology allows screeners to see through clothing to bare skin and to detect prosthetics, including breast prostheses and prosthetic testicles. The scanners also reveal other medical equipment such as colostomy bags and catheters. These discoveries could require potentially embarrassing physical inspections. Travelers have complained that they were singled out for scans or pat-downs because of their gender. Others reported that when they opted not to be scanned they were subjected to invasive pat-downs in their genital areas.

According to one of its documents, *Procurement Specification for Whole Body Imager Devices for Checkpoint Operations*, the TSA, part of the Department of Homeland Security, requires that their full-body scanners export image data in real time, and there are confirmed cases of the government storing images. In August 2010, researchers discovered that the U.S. Marshals Service had saved thousands of images from a millimeter-wave

scanner. Although the TSA insisted that its scanners do not save images and do not have the capability to save images when they are installed in airports, on November 16, 2010, 100 of 35,000 stored body scan images were leaked online and posted by Gizmodo. People opposing full-body scanners have argued that after a successful terrorist attack the machines would not have the capability to save images for later inspection to discover why the scans had not worked.

Opponents of full-body scanners argue that strip searches without probable cause violate basic human rights. They contend that governments do not have the right to make strip searches routine and mandatory, regardless of whether the strip search is done by physically removing clothes or by using technological means to remove the clothes. They argue that full-body scanners and TSA pat-downs are unconstitutional. A study about scanners and pat-downs titled "Full Body Scanners: Full Protection From Terrorist Attacks or Full-On Violation of the Constitution?" came out in the fall 2010 issue of the *University of Denver Transportation Law Journal*. The study argued that the full-body scanners are unconstitutional in the United States because they are too invasive and not effective enough because the methods are too inefficient.

TSA has installed new machines called L3 Millimeter-Wave Body Scanners that show only a generic male or female human form with no features instead of the individual body image that the Rapiscan equipment produced. Nearly 200 of the scanners currently in use in more than 30 airports across America will be removed.

Opponents of full-body scanners still consider the revised scanners an unconstitutional strip search, even though the operators see an edited version of the image. The machine still captures a naked image, and there is no guarantee that the government or private companies will not store the images if a terrorist attack is successful.

Trusted and Untrusted Passengers: Trusted Traveler Programs

Along with the U.S. government and the travel industry, aviation security leaders are developing plans to steadily move into a risk-based system of passenger screening. Government officials who want screeners to focus on travelers who present

more of a security threat support the idea, and they are eager to implement what they call the passenger differentiation concept.

U.S. Customs and Border Protection (CBP) uses a risk-based approach to screen all travelers entering the United States, combining automated advanced data with intelligence and new biometric travel documents. CBP has established expedited "trusted traveler" programs that facilitate entry for frequent travelers who have passed prior screening of their biographical and biometric data. The programs allow preapproved low-risk travelers expedited processing at ports and make it faster and easier for visitors and business people to enter the United States. Expedited traveler programs allow CBP officers additional time to focus on higher risk unknown travelers.

CBP trusted traveler programs include Global Entry, SENTRI, FAST, and NEXUS. At U.S. international airports, prescreened Global Entry members experience expedited entry benefits such as no processing lines, no paperwork, and reduced wait times. Global Entry streamlines airport screening, allowing members to use Global Entry kiosks at select airports to swipe their passports, scan their fingerprints, and make customs declarations without waiting in line.

Collecting and sharing information about passengers is at the center of the risk-based approach. Governments use data that individual passengers have volunteered by applying for trusted traveler programs, as well as information obtained through terrorist watch lists, criminal background checks, and border checkpoint encounters. For passengers on international flights, much of the data in their records is already shared with the Department of Homeland Security (DHS), although DHS has agreed to filter out certain identifying records like meal preferences.

As security measures turn more to identifying trusted and suspect travelers, the federal government is scrutinizing data that airlines and travel agents have collected about their customers, from birth dates and passport numbers to potentially confidential details like travel itineraries or group discount codes. The federal government would also like to employ more behavior detection officers to question passengers in security lines, a technique that Israel uses, although the Government Accountability Office has criticized the way the program

operates in the United States, contending that it has not met scientific standards of validation.

The prospect of using passenger data for airport screening decisions as well as border control had created a divide between European security officials and their American colleagues. As governments and airlines work out the details of distinguishing between trusted travelers, who are eligible for lighter screening, and people who will receive more intense screening, civil liberties groups and some European regulators are questioning the wisdom of using vast amounts of personal data to decide which travelers can be trusted and which cannot be or will not be allowed to fly at all. Although sharing passenger data across borders is already happening, the process presents some complex challenges. Governments have to decide when and how to recognize trusted travelers from different countries and how to deal with nations they do not trust or with unequal human rights issues asking for passenger data.

The TSA has an expedited security program called TSA Pre✓™ and it encourages passengers to apply for global entry to extend eligibility for early check-ins (PreCheck), but some travelers discover to their dismay that applying for trusted traveler status gets them an untrusted label instead. Some people do not have any idea why they were rejected, and other people have been denied because of minor brushes with the law years earlier. If all adults who do have a criminal record—an arrest or a conviction—are rejected, that could exclude millions of people from the trusted traveler pool and hinder the government's goal of including half of all airline passengers in the trusted category.

Travelers who are on the TSA PreCheck Disqualification List can also be excluded. The TSA said that this list would be generated by the TSA Performance and Results Information System, which keeps records of violations of federal, state, local, or international criminal law. It describes the list as a roster of individuals disqualified from eligibility from TSA PreCheck temporarily or permanently because they have violated security regulations. Violations range from getting caught with a loaded firearm at a checkpoint to disobeying aviation security regulations at the airport or onboard aircraft.

When TSA approves a passenger for expedited screening, authorities embed the information in the barcode of the passenger's boarding pass. TSA scans

the barcode at designated checkpoints and the passenger may receive expedited screening. Only Delta Air Lines, United Airlines, and US Airways notified passengers of eligibility on boarding passes in early 2013, but other TSA Pre✓-participating airlines are implementing similar programs.

As civil rights groups and passengers learn more about trusted traveler programs, debates about qualifications, the amount of personal information stored and traded, and implementation and enforcement of the programs will likely become more heated. Some airline experts argue that a system that uses passenger data to assess an individual's security risk should meet important criteria. These criteria include that the system must be proven to effectively capture terrorists, it must identify and capture terrorists without violating privacy rights, and it must avoid negative side effects like discrimination. These are challenging goals for the Transportation Security Administration to meet.

Cyber Terrorism

If cyber terrorists are able to successfully invade one of the U.S. airport systems and cause a problem or shut down operational software that controls all airplane schedules, that single terrorist act may affect other domestic and international airports that are connected to that airport as well as the region where the airport is located. An airport shutdown would cause a ripple effect throughout the domestic and international economy.

Many Pentagon officials believe that terrorists may use strategies intended to eliminate U.S. military technological superiority, but because the U.S. military is significantly supported by civilian technological products and services, including communication systems and electronic and computer software, future conflicts may blur the distinction between civilian and military targets. Terrorists are becoming more adept at using the Internet to communicate with Web sites, chat rooms, and e-mail. They raise funds and covertly gather intelligence on future targets on the Internet. Terrorists are becoming Internet savvy enough to wage a concerted cyber attack against U.S. computer systems.

Most security experts agree that a most likely plan of action for a terrorist group would be to try to disable U.S. computers or communications systems to intensify or supplement a conventional terrorist bombing or other major attack. A

terrorist computer network attack could involve using malicious code as a weapon to infect computers. The code could exploit weaknesses in the software, in the system configuration, or in the computer security systems of an organization or individual user. Another type of terrorist cyber attack is using stolen information to enter restricted computer systems and gain access to their wealth of information.

Cyber attacks by terrorists may prove to be more damaging than physical attacks because they involve disruptive technologies that could produce unpredictable consequences or give the terrorists an unexpected advantage. As in the case of the al Qaeda attacks on the World Trade Center and the Pentagon on September 11, 2001, terrorist physical attacks destroyed important computer databases and disrupted civilian and military operations. Combined with focused and accurate cyber attacks, terrorists could inflict great damage. Most chillingly, cyber terrorists can disrupt communications among the people who must defeat them.

Airline Passengers Versus Blacklists

The United States government had already implemented airport security measures before September 2001, largely in response to the airplane hijackings of the 1970s and 1980s. After the terrorist attacks of 2001, government agencies under the Bush and Obama administrations expanded passenger screening lists, especially after Richard Reid, the shoe bomber, attempted to blow up an American Airlines plane in 2002, and Umar Abdulmutallab, the underwear bomber, nearly detonated a bomb strapped to his underwear on Christmas Day 2009.

For ordinary airline passengers, dealing with lists and their overlaps maintained by government antiterrorism agencies can be as complicated as boarding an airplane. The Intelligence Reform and Terrorism Prevention Act of 2004 established the National Counterterrorism Center, which is a clearinghouse for the various terrorist screening systems and watch lists of the intelligence community and its counterterrorism mission. The National Counterterrorism Center controls a massive database called the Terrorist Identities Datamart Environment (TIDE), including the names of more than 740,000 people. Fewer than 2 percent of them are U.S. citizens or legal permanent residents.

The Terrorist Screening Center of the Federal Bureau of Investigation (FBI) maintains the Terrorist Screening Database (TSDB), which draws much of its data from the National Counterterrorism Center database. In 2010, the TSDB contained information about 423,000 people, about 5 percent of them U.S. citizens and permanent legal residents. The FBI also maintains a smaller list called the Selectee List, which according to 2009 news reports contains the names of 14,000 people who are subject to mandatory airport screenings. The Transportation Security Administration originally oversaw the list but delegated it to the FBI's Terrorist Screening Center.

The Terrorist Watch List

The Terrorist Screening Center maintains a massively larger list than the No Fly List called the Terrorist Watch List, which as of 2011 contained about 400,000 names of people suspected of some involvement with terrorism. By 2013, the list had grown to 875,000 names. The list documents names of convicted terrorists and terrorists at large, registered sex offenders, and people suspected or convicted of drug trafficking.

Critics, including the American Civil Liberties Union (ACLU), contend that the Terrorist Watch List violates individual civil liberties and due process rights because of the possibility of ethnic, religious, political, and economic profiling. Critics say that the Terrorist Watch List is a privacy violation and is based on government secrecy. They argue that determined terrorists can easily circumvent the list by obtaining false identification and other illegal means.

The No Fly List

After September 11, 2001, the Transportation Security Administration (TSA) originally maintained the No Fly List to detain passengers who possibly could be flying somewhere to commit a terrorist act or train in a terrorist camp. Eventually the TSA delegated management of the No Fly List to the FBI's Terrorist Screening Center. The number of names on the No Fly List ebbs and flows with the degree of terrorist threat and amount of intelligence reporting. In 2012, the list contained about 21,000 names including, at one time, that of Senator Edward Kennedy of Massachusetts. The Secondary Screening Selection earmarks

questionable passengers for a second, more thorough screening.

The names of the passengers on the list are not publicized. People are not informed that they are on the list and discover their inclusion only when they are stopped and barred from boarding an airplane or exiting an airport. Several people on the No Fly List have brought suit in federal courts to have their names removed from the list, after being stranded far away from home, since the No Fly List extends to shipping as well. Others have charged that the FBI offered them a deal to become an FBI informant in exchange for removing their name from the list.

In March 2013, the ACLU filed a federal lawsuit in Oregon challenging the constitutionality of the No Fly List on the grounds that the government violated Fifth Amendment due process rights of 13 Americans, including four veterans. The ACLU charges the government placed the passengers on the No Fly List and refused to furnish any explanation or hold a hearing to clear their names. Citing the state secrets doctrine, the government refuses to confirm or deny the presence of names on the No Fly List.

TSA Screeners Versus Terrorists

On Friday, November 1, 2013, Paul Anthony Ciancia, 23, walked into Los Angeles International Airport wearing military fatigues and pulled an assault weapon out of his bag. Opening fire, he killed TSA officer Gerardo Hernandez and wounded two officers and several passengers. Hernandez, a behavioral detection officer trained to look out for suspicious activity, was the first TSA worker to die in the line of duty. His death reignited the debate about the role of airport screeners and how they can protect themselves and the public they serve. Ideas range from giving screeners guns to removing their badges (which resemble police badges). Congress has the power to institute these two changes.

According to some critics, the logistics of providing guns to more than 45,000 officers would be problematic. As of 2013, the federal air marshals were the only TSA officers carrying weapons, and most of them have backgrounds in law enforcement or the military. Arming TSA agents would be time consuming and would introduce weapons into checkpoints where deranged passengers could grab

them and turn them against airport personnel and others. A change in operations would also distract TSA personnel from their mission of finding people and items threatening aircraft.

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See Also: Airport Security; Aviation Safety, Dangerous Goods Transport and; Social Impacts of ITC; Terrorism, Transportation Systems as Targets of.

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Airport Transit Connections

The vast and rapid expansion of air transport and the mushrooming of airports have changed the way our society thinks and acts regarding the mobility of people and cargo. Sometimes clashing with and sometimes in concert with the priorities of cities, rural areas, and broad regions containing both, the growth of aviation has raised many questions about how best to tie in civil aviation with surface modes of transportation.

Intermodal Ideals

Ground transport modes, both road and rail, are the great connectors to air transport. Between the two, the highway—and its attendant need to acquire land

for shoulders, ramps, parking facilities, and support structures—has long held the dominant share and made the greatest imprint on airport ground-link planning and practice. However, the very popularity of air travel and transport has led to overcapacity, delays, and congestion on the ground, as limits have been reached for automotive and trucking options.

Congestion, air and noise pollution, and community resistance to land-acquisition policies have led many municipalities, counties, and regional planning authorities to consider rail links between urban centers, suburban and rural areas, and the airports that serve them. This movement has been echoed at the national level.

The construction of monorails, light rail connectors, and intercity rail links, including the main U.S.-based passenger carrier, Amtrak, has increased in the last two decades. Many large cities—New York and Washington, D.C., in the United States; Osaka and Tokyo in Japan; Paris and Frankfurt in Europe to name a few—have established effective rail links to their major airports, with continuing success as gauged by such metrics as usage trends, safety, energy savings, and return on investment.

At the same time, there are multiple ways to improve the handling of highway-based transit to and from airports; this mode will certainly be the first choice for many years to come in most localities. Therefore, the design, planning, and improvement of such efficiency-raising, congestion-cutting concepts as park-and-ride, subsidized shuttle bus service, adaptable traffic flow control systems, advanced people-moving technology in and around terminals, and related ideas will continue to grow in importance. Metropolitan and regional planners need to consider and adapt each of these in turn; they are supported in this by advocacy from within the aviation industry, as well as from citizens groups and from various federal measures.

Leading by Legislating

In crafting the Federal Aviation Administration (FAA) Modernization and Reform Act of 2012, legislators working with the chief administrators of the FAA moved to relax some standing restrictions on the use of airport passenger facility charge (PFC) revenues, specifically so as to enable airports to invest in transit connection infrastructure such as intermodal staging areas, including rail links to urban areas and intercity destinations.



A sign for a light rail transit connection in Terminal 1 of the Salt Lake City International Airport in Utah in July 2013. Rail links have grown increasingly popular in planning for U.S. airports.

The FAA and its congressional sponsors sought to support “airport and intercity passenger rail operations that can improve connectivity between airports and intercity passenger rail facilities and stations,” and even to find ways to defray the costs and enhance the benefits “of the implementation of more integrated scheduling between airlines and Amtrak or other intercity passenger rail carriers achieved through code sharing arrangements.”

The authors of the FAA bill emphasized that there already were a range of related legislative bills under consideration in the U.S. House and Senate that would, among other goals, streamline administrative requirements so as to encourage airport authorities to impose new PFCs “to finance an intermodal ground facility” and initiate a program to construct “off-airport intermodal ground access projects related to movement of airport passengers” and goods.

In a similar vein, the White House, through its National Aeronautics Research and Development Plan of 2010, in its section on improving fundamental mobility in air transport, pointed to the need to develop “airport terminal designs that facilitate passenger throughput, including movement between surface and air transportation modes.”

Initiatives like these built upon more longstanding laws and funding structures. One such was the Intermodal Surface Transportation Act of 1991 (ISTEA), which shifted federally supported transportation planning from what had been a virtually all-highways focus to a new vision of an integrated and fully intermodal transportation system. ISTEA altered reimbursement rates to states engaged in various major transit projects, seeking to influence capital outlays toward this new vision.

A result of the establishment of ISTEA was to strengthen metropolitan planning organizations (MPOs) by mandating their participation in various project selection roles. This mandate, along with increased direct funding of MPOs by the U.S. Department of Transportation, has tended to enhance the abilities of MPOs to partner across regions and to negotiate with airports, port facilities, and other transit and transportation decision-making businesses and bodies. Along with these actions, ISTEA required major urban areas to develop long-range transportation plans entailing much public comment, ensuring considerable focus on environmental and zoning issues, and embodying the new intermodal ideals.

There is reason to be optimistic that both commercial interests and public administrators can see eye-to-eye on the issues of airport–transit connections and will develop improved ways to plan and construct smart solutions.

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See Also: Air Travel; Airport Hubs; Airport Parking and Ground Transportation; Airport Planning; Intermodal Surface Transportation Efficiency Act; International Travel; Metropolitan Planning Organizations; Monorails.

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studied in terms of conflicts between animals and aircraft, with less known about the effects of airports on habitats and specific species. Reducing the effects of noise involves either reducing it at the source through quieter engines or changes in operations (known as abatement), or reducing its effects through land use controls or by soundproofing existing structures (known as mitigation). Air pollution is mitigated through source reduction, both of aircraft and ground vehicles. At some point, however, without further technological improvements, the only mitigation that is possible within the constraints of current technology is to reduce (or at least not increase) the number of flights, leading to the question of how much more expansion of airport infrastructure is possible in certain locations.

Noise Pollution

Noise exposure is determined for individual airports by averaging aircraft noise over a 24-hour period to produce DNL (Day-Night Level) contours, measured in decibels. Normal conversation takes place at a level of about 60 dB, which implies that living in an area at or above the 65 DNL would make conversation extremely difficult. Because the noise contours are averages, however, this means that periods of quiet alternate with sound levels up to 100 dB when a plane passes overhead, resulting in an average of 65 DNL. Noise lines are mapped out as contours similar to a topographic map, usually drawn at the 75, 70, and 65 DNL levels, and no contour higher than the 75 DNL usually extends beyond airport property. DNL levels are assessed via computer modeling, including data on the mix of aircraft at a particular airport, how noisy those aircraft are, how many operations there are per day, and the height of the flight paths. These same factors are then projected five or more years into the future, thus requiring input from airlines as to their future operations. Noise between 10 P.M. and 7 A.M. is given a weight of 10 extra decibels due to less background noise and the fact that most residents are sleeping. Since the decibel scale is logarithmic, this means that nighttime flights (or "events") are considered 10 times as noisy as daytime ones. The levels may be checked via sound monitoring, or the computer projections may be used without ground verification.

Within the United States, the Federal Aviation Administration (FAA) and Environmental

Airports, Environmental Issues and

The environmental effects of airports are often considered to be externalities or side effects that can be alleviated by some sort of mitigation. Increasingly, however, environmental externalities are feeding back into the system, affecting the expansion of airport infrastructure. It seems likely that the magnitude of aircraft movements will increasingly be determined by where citizen opposition on environmental grounds is minimal, which makes it necessary to understand what those environmental limits might be.

There are three main types of environmental effects from airports: noise and its consequences for the human environment, air pollution at local and global scales, and impacts on wildlife. Noise has been well studied in terms of its effects on health (minimal) and property values (small but significant), air pollution has been shown to have significant impacts on health and well-being in the airport vicinity, and wildlife impacts have mostly been

Protection Agency (EPA) have agreed that residential land uses are officially incompatible with airport operations within the 65 DNL contour. About 5 million people within the United States lived within such a line in 1990, although after international restrictions on aircraft noise went into effect in 1990, that number dropped to 323,000. The FAA's official policy is that land use planning should be left up to local communities, with safety restrictions on height and population density the only exceptions. However, even in communities where the airport is taken into account in land use planning by locating residential development outside the noise contours, future runway configurations can negate such planning by changing those contours and exposing new populations to noise, as seen recently in Minneapolis–St. Paul and Chicago.

There are two main sets of concerns about the effects of aircraft noise on residents: health risks and property values. Differing physical, psychological, and socioeconomic characteristics mean that the same level of noise can affect individuals quite differently. Nevertheless, there is strong evidence that sleep patterns and concentration are disrupted and that quality of life and health can be reduced up to 10 miles from the airport, or over three times as far as the 65 dB noise contour extends. At the same time, there is a general consensus that aircraft noise lowers residential property values: an average decrease in property values from 0.4 to 1.1 percent occurs for every 1-dB increase in DNL. In other words, a house located in the 64 DNL contour is worth between roughly half a percent to a percent less than if it were located in the 63 DNL contour.

Noise Reduction

Reduction of aircraft noise can be provided in one of three ways: mitigating the effects of the noise, as with soundproofing; abating noise at the source via technology; or changing flight operations. Many airports use all three methods. Because of concern over lost property values due to aircraft noise, the FAA will fund mitigation to residences and other buildings deemed incompatible with this noise level, partially via passenger facility charges (PFCs) attached to airline tickets. Approximately 70 percent of these funds go to the acquisition of property and relocation of individuals, while nearly 20 percent go toward soundproofing. Only 3.4 percent of these funds go toward planning to

prevent noise incompatibilities in advance via land use planning or land acquisition. Soundproofing is generally preferred by residents over relocation because they are able to stay in their neighborhoods, by cities because of the maintenance of neighborhoods and tax base, and by airport operators because of the lower cost and less disruption to neighborhoods.

Source reduction of noise, of course, is the mitigation method preferred by residents but opposed by airlines, leaving airport operators often caught in the middle. There are two ways to reduce the noise heard on the ground: operations changes, such as flight tracks that take aircraft over nonresidential land uses, or changes to the aircraft themselves to make them quieter. Operations changes are generally considered voluntary, since the pilot has ultimate control over where his or her plane flies once it is in the air. Frequent communication is thus required between the air traffic control tower (managed by the FAA) and the airport operator (in the U.S. context, usually a local unit of government or independent regional authority) to make sure the operational changes are being implemented. Operations changes often simply redirect noise to another area, spreading out the effects rather than reducing them and potentially pitting airport neighbors against each other.

Aircraft themselves are the most permanent site of noise reduction, and as new technology has been made available, the sound produced by individual aircraft has decreased dramatically. For example, one of the first long-haul jet aircraft was the Boeing 707. On takeoff, a 707 creates a one-time exposure of 65 dB or higher to an area covering 82 square miles. The comparably sized 757, introduced in the early 1980s, exposes only 14 square miles to the same sound level, while Boeing's new 787 has a footprint of only 0.7 square miles. This tremendous decrease, however, is offset at many airports by the tripling in air traffic that has taken place over the same time period.

The model that is used to determine the DNL contours is more sensitive to noise than to frequency, so the contours have generally grown smaller with time. However, residents may be equally sensitive to the level of noise and the number of noise events (that is, flights), making the DNL method an increasingly less accurate reflection of the level to which residents are affected by



A Boeing 747 descends over a residential area on approach to Heathrow Airport outside of London, England, in July 2004. Advancements in aircraft noise reduction have been offset by a significant increase in air traffic since the 1980s.

airport noise. Other methods, such as measuring the minutes in the day during which noise exceeds the 65 dB limit, could more accurately reflect the impact on the human environment.

Air Pollution

Air pollution is increasingly becoming a concern of both airport neighbors and the larger community. Airport pollution comes from three sources: groundside traffic such as cars and trucks, taxiing or idling aircraft, and overflights. At the local level, airports are often given exemptions from state and federal emissions laws, despite the fact that they can be among the highest polluting facilities in a state. Nor are airports required to report their toxic emissions totals in the National Toxic Release Inventory. Pollution at a global level may be an even greater cause for concern because emissions at high altitude have a more direct effect on global warming than those at ground level.

There are three main types of pollutants produced by aircraft engines: oxides of nitrogen (NO_x), carbon monoxide (CO), and hydrocarbons or volatile organic compounds (VOCs). Most NO_x emissions are actually produced by motor vehicles, though NO_x is the

primary pollutant produced during the high-power maneuvers of takeoffs and cruising. VOCs and CO predominate during low-power operations such as taxiing, meaning that delays on the ground translate to more emissions of these compounds into nearby areas. Both of these types of emissions are actually decreasing around major airports because of technological changes. However, in an ironic trade-off, the changes that enabled engines to be quiet enough to meet new requirements for noise also mean that those engines produce more NO_x .

Though it can be difficult to separate the effects of background urban pollution from that emitted by the airport, a number of studies indicate that proximity to a major airport does result in some increased health risks. A study commissioned by Park Ridge, Illinois, for example, found a higher cancer risk than is considered acceptable under federal standards for residents not only in municipalities adjacent to O'Hare International Airport but for 98 total municipalities in the metropolitan area. A study in New York chose the cutoff point of 5 miles away from an airport and found that living within this distance led to an increased risk of hospital admissions for respiratory conditions. Finally, because jet fuel is not unleaded, elevated levels of lead in children's blood have also been observed near major airports, including a 2.1 percent increase within a mile and up to a 4.4 percent increase within a third of a mile.

At the same time, studies on increased cancer rates in airport-adjacent neighborhoods have been largely inconclusive. Though most studies have shown that emissions in the area of airports are no worse than in urban areas in general, one exception is a study commissioned by the town of Winthrop, Massachusetts. Winthrop is located at the end of a peninsula in Boston Harbor, so that the only emissions come from residential auto trips—and aircraft. Here, the study did find a correlation between residents' proximity to Boston Logan International Airport and the incidence of respiratory diseases, suggesting that were it possible to more carefully parse out air pollution from the airport itself as compared to its surroundings, the effects on human health might be more noticeable.

Impacts on Wildlife

The bulk of the research on the environmental impacts of airports regarding wildlife has to do with

their interference with aircraft. Between 1990 and 2009, there were 99,411 animal strikes reported in the United States to the FAA from 77 different species. While bird strikes are the best known, particularly after US Airways Flight 1549 crash-landed into the Hudson River in 2009, an analysis of these data indicates that deer and dogs are actually the most hazardous when considering the likelihood of damage to the aircraft. Of bird species, geese are the most hazardous because of their size, with vultures posing significant problems as well because of their propensity to fly at higher altitudes. It is important to note that the specific ecological conditions of a particular airport and its surroundings need to be considered when determining the threat that wildlife pose to aircraft and the possible ways to mitigate that threat.

The primary means of reducing the hazards that wildlife pose is by making the airport and its surroundings as unattractive to wildlife as possible, which therefore comprises the main environmental impacts of airports on wildlife. For example, the deliberate removal of wetlands to discourage birds and other species from nesting or feeding (aside from wetland removal associated with airport construction) is a common management practice. Other types of land uses such as landfills and agricultural fields that are known to attract birds are therefore also undesirable, even though these land uses have high noise compatibility with airport operations compared to residential or commercial land. At the same time, management techniques such as frequent grass mowing to discourage bird nesting may make that same habitat more attractive to other species that prefer short grass, meaning that trade-offs need to be considered in airport environmental management.

Aside from their habitat being altered or removed to reduce the risk they pose to aircraft, there are other impacts on the ecological conditions in the airport vicinity coming from the contamination of soil and water, potentially stretching miles beyond airport borders. Studies have found lead, cadmium, per- and polyfluorinated compounds (PFCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), benzotriazole, and tolyltriazole, all of which have been classified as either toxic or probable carcinogens, to be present in significant amounts in soil and/or water adjacent to or downstream from major airports.

Depending on the climate, significant amounts of propylene glycol may be used to de-ice aircraft, and potassium acetate or urea may be used to keep taxiways and runways from freezing over. Both of these chemicals run off into waterways as well. Fuel storage units can leak or spilled fuel can wash off aprons and taxiways, as can chemicals from fire-fighting equipment from drills or actual incidents. Because of the hazardous nature of any liquids on airport pavement, airport pavement systems are designed to quickly remove surface runoff, although such systems will contaminate groundwater if they leak.

The implications for wildlife of these environmental contaminants can be significant, although relatively little research has been done in this regard. For example, one study in Milwaukee found that 40 percent of the water samples taken downstream of the airport exceeded the toxicity point for aquatic life. An Italian study showed that honeybees near Rome's Ciampino Airport accumulated the highest lead levels of any bees sampled in the region, probably from jet fuel fumes or contaminated soil. Since many airports are only just beginning to monitor the extent to which their operations contaminate surrounding water or soil, much research remains to be done on the impacts to wildlife.

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See Also: Aircraft Engine Emissions; Airport Planning; Aviation Safety; Wildlife Strikes and; Carbon Monoxide Emissions; Environmental Impacts; Lead Pollution; Nitrogen Oxides; Noise Pollution and Airplanes; Volatile Organic Compounds.

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Alternative Automotive Fuels

Alternative fuels (AF) can be defined as substitutes for conventional fuels relying on hydrocarbons and petroleum. They come from non-crude oil resources and include all vehicular fuels other than diesel fuels and gasoline. Traditional fuels have been the primary automotive fuels used since the early part of the 20th century. In recent years oil has supplied as much as 96 percent of the fuel for the U.S. transportation fleet. The United States burns about 13 million barrels of oil a day for its transportation system. Transportation represents about 70 percent of U.S. oil consumption and 30 percent of U.S. greenhouse gas emissions, with gasoline and oil fuels accounting for 60 percent of oil consumption.

Types

The most commonly used alternative fuels for transportation are first-generation liquid biofuels/agrofuels (for example, ethanol and biodiesel). The term *biofuels* also includes fuels derived from forests such as wood and charcoal, while the term *agrofuels*

derives from nonforestry activity, including agricultural crops. Agrofuels/biofuels are fuels obtained as a product of energy crops and/or agricultural by-products, fuel crops, wood or herbaceous crops grown specifically for their fuel value. Second-generation liquid biofuels are produced from nonedible parts of agricultural feed stock such as husks and hay. While some support production of ethanol and diesel from agricultural waste products and nonedible plant material, this is not yet being done on a large scale. Third-generation liquid biofuels are composed of other organic material, such as algae cultivated for this purpose. Fourth-generation liquid biofuels result from the use of microorganisms and carbon monoxide to generate fuel.

Although conventional fuels still comprise the majority of the fuels consumed in the transport industry, AF are on the rise. Countries like Brazil, Italy, and New Zealand have developed vehicle transportation systems based on AF. In 2004, 50 percent of Brazilian cars ran on bioethanol and in 2007 the number was 80 percent. In the United States, recent proposals from the Barack Obama administration included using \$2 billion in funding coming from federal gas and oil royalties over a 10-year period to pay for research supporting AF cars. The goal of this plan was to support replacements for hydrocarbons as the primary fuel used by cars, trucks, and buses. The Obama administration and others have argued that AF are cheaper, more sustainable, and can promote energy security, freeing countries from depending on nations supplying oil that are considered unstable, in conflict zones, or less democratic.

In general, attempts are being made to reduce emissions from gasoline and diesel as well as to develop AFs. The lead additives in gasoline have been banned in almost all countries. As a substitute for such additives, oxygenated supplements like ethanol and methanol have been used. Mukesh Khare and Ptrateek Sharma explain that "the commonly used oxygenate in gasoline blends are methanol, ethanol, t-butyl alcohol (TBA), methyl t-butyl ether (MTBE), and ethyl t-butyl ether (ETBE)." Oxygenated gasoline can reduce carbon monoxide (CO) and hydrocarbon (HC) emissions, have a higher octane rating, and lower emissions from older vehicles. Some "reformulated gasoline" (RFG) may lack oxygenates, although the terms have been used interchangeably. Gasoline is reformulated to both reduce evaporative emissions

(or volatility) and sulfur. Reformulated gasoline can reduce nonmethane HCs in contrast to fuels only using HC. In the United States, Congress mandated the RFG program in the 1990 Clean Air Act amendments. RFG is mandated in cities with high levels of smog, currently used in 17 states and the District of Columbia. Recent estimates state that about 30 percent of gasoline sold in the United States was reformulated. The Environmental Protection Agency (EPA) reports RFG has contributed to reduced smog levels and “about 75 million people breathe cleaner air because of RFG.”

Biodiesel is a kind of AF using renewable resources that can safely be used in any modern diesel engine. Biodiesel is usually produced from oil-producing plants like rape seed, oil palms, soybeans, sunflowers, and jatropha. Vegetable oil is pressed from oleaginous/oleiferous (oil-rich) plants and

converted through a process called esterification; it can also be made from waste cooking oil. Biodiesel initiatives have been started in almost every country in the world.

Fat can be transformed into fuel, recovering energy and recycling wastes that otherwise might have been flushed down drains or dumped in landfills. Diesel provides low output per kilogram and liter, creating higher initial costs. Yet, it still provides lower overall operational costs. David Sandalow explains that “diesel engines are 30 percent to 40 percent more fuel efficient than comparable gasoline engines.” In the past, the use of such engines in the United States has “been limited by dirty exhaust and a reputation for poor quality,” but improvements are under way. Diesel engines perform “especially well carrying heavy loads at low speed” and “are used widely in large trucks and heavy equipment.” They have “better torque and greater durability than gasoline engines.” The Worldwatch Institute in Washington, D.C., suggested that biofuels could provide 37 percent of transportation fuel used in the United States within the next 25 years. With a doubling of automobile fuel economy, such fuels could provide 75 percent of such fuel. In contrast, the U.S. Energy Information Administration has discussed scenarios involving a far more modest reduction in fossil fuels.

Environmental Principles

Sustainability can be assessed based on the environmental, social, and gendered impacts of different fuels, with impacts related to the quantity of potential damage to the ecosystem and the qualitative impacts of different fuels. Christopher Knittel reports several environmental costs associated with burning petroleum: “The transportation sector accounts for 67 percent of carbon monoxide emissions, 45 percent of nitrogen oxide emissions ... and 8 percent of particulate matter emissions.” This leads to health problems, smog, and infant mortality. The burning of “a gallon of gasoline causes roughly 25 pounds of carbon dioxide to be emitted into the atmosphere, which raises the risks of destructive climate change.” Some of the health effects of pollutants in conventionally fueled vehicles include a reduction in the capacity of the blood to transport available oxygen to tissues (from CO), an increase in the vulnerability to respiratory infection (from nitrogen oxide),



A student technician with the U.S. Department of Agriculture compares soil solution samples to be used in biofuel crop research. Jatropha is one plant being considered as a possible future feedstock for biofuel production.

and various toxic and carcinogenic effects (from hydrocarbons).

In assessing the environmental impacts of alternative fuels, various principles must be considered. First, some AFs are more ecologically sustainable than others. In other words, even if a fuel source is classified as an AF, it does not necessarily have to be sustainable. Khare and Sharma note, “a decrease in the aromatic content of gasoline may lower carbon monoxide ... and hydrocarbon ... emissions but may increase nitrogen oxide ... emissions.” Yet, “a major advantage of fuel modification is that it often can take effect quickly and begin reducing pollutant emissions immediately.” AFs can emit toxic organic compounds, including benzene, toluene, 1,3-butadiene, formaldehyde, and acrolein. Biodiesel is non-toxic and biodegradable, however. The ability of a vehicle using AF to produce low pollutant emissions can depend on how much pollution control equipment is deployed.

Second, the efficiency regime can influence outcomes. Greater growth can wipe out a portion of sustainability gains from using a less polluting fuel. For example, given the “Jevons paradox,” lowering prices of fuels may increase their use, thus potentially lowering the sustainability advantages of AF. For example, if fuel A is 50 percent cleaner than petroleum (fuel B), substantial increase in the use of cars and other vehicles can wipe out the aggregate advantages coming from using fuel A rather than fuel B. In the United States, travel on all roads and streets was 1,933,289 million vehicle miles, increasing to a peak of 3,030,794 million miles in 2008 (the year of the latest financial crisis), but decreased to 2,948,804 million miles in 2012. In general, AFs have a lower energy density, requiring greater onboard storage than diesel or gasoline. Yet, some AFs provide more energy per kilogram than gasoline, so AFs can be more efficient.

Given these potential constraints, some point to the use of electricity driven by more sustainable and less damaging sources as a supplement, if not an alternative to AFs.

Bioethanol

Bioethanol is essentially alcohol made from agricultural raw material called feedstock. Bioethanol is usually made from sugarcane, maize, wheat, sugar beets, sorghum, and starchy tubers like cassava. Ethanol can be made from any biological

material, but sugary crops are easiest to ferment. Ethanol is the most widely used biofuel, sourced primarily from corn, in the United States. In contrast, sugarcane is the main feedstock used in Brazil, with Louisiana supplying this crop as well. Cellulose is another source for ethanol and can come from waste paper, agriculture residue, and switchgrass. Ethanol is cleaner, less toxic, and less corrosive than methanol. Carbon monoxide and nitrous oxide are lower in ethanol than gasoline. Yet, some claim that producing ethanol may increase carbon dioxide. Ethanol emits 70 percent to 75 percent less CO₂ compared to petrol/gasoline during combustion, but the effect has been disputed by those examining the entirety of the production and distribution system. Ethanol is a widely contested biofuel because of its sourcing from edible raw material. To fill the tank of an SUV with ethanol takes 450 pounds (20 kilograms) of corn—the equivalent of one person’s total caloric need for a whole year.

In reviewing various studies, Knittel reports one that found that the use of Brazilian sugarcane ethanol could reduce pasturelands, leading cattle farmers to cut down rain forests. Thus, “once indirect land use effects are considered, corn-based ethanol can have nearly twice the greenhouse gas emissions of gasoline.” Another study Knittel cites found that “once changes in both international trade and crop yields are accounted for, corn ethanol results in fewer greenhouse gas emissions than gasoline, despite indirect land use changes.” The Global Studies Initiative has raised questions about how biofuel consumption could displace land and markets used to produce food, animal feed, and a smaller volume of industrial products. Women are more vulnerable than men to the effects of displacement because they often lack land tenure and access to both agricultural inputs and markets.

Ethanol can be used as the principal fuel in a vehicle as in E85 (85 percent ethanol and 15 percent gasoline) or primarily as a supplement, as in E10 (90 percent gasoline and 10 percent ethanol). With a lower heat value than gasoline, more ethanol is needed than gasoline to drive a vehicle an equivalent distance. Some engineers interviewed by *Consumer Reports* said that “E85 fuel economy could approach that of gasoline if manufacturers optimized engines for that fuel.” *Consumer Reports* notes a study by David Pimentel at Cornell

University stating that the growth of corn and its transformation into ethanol required 30 percent more energy than the ethanol contains. In contrast, Michael Wang at Argonne National Laboratories says ethanol produces 35 percent more energy than required by its production process.

A report in the *New York Times* on March 16, 2013, notes that “nearly 10 percent of the nation’s ethanol plants have stopped production over the past year, in part because the drought that has ravaged much of the nation’s crops pushed commodity prices so high that ethanol has become too expensive to produce.” In addition, “blends calling for a higher percentage of ethanol have yet to catch on widely in the marketplace.”

The congressional goal to promote E10 was based on the assumption of increased demand for fuel. Yet, this demand has gone from 9.7 million barrels a day in 2007 to only 8.7 million barrels in 2013. With corporate fuel economy standards expected to double average mileage by 2025, this suppresses oil demand (which could rise with population growth).

Biodiesel

Biodiesel is produced by reacting animal or vegetable fats with ethanol or methanol, creating a fuel that is similar to diesel in its physical characteristics. Khare and Sharma cite the study by Salvatore Alfuso and colleagues suggesting “higher particulate emissions in comparison with conventional diesel fuel” and costs that are “substantially higher than conventional diesel.” Yet, a later (1998) biodiesel life cycle study jointly sponsored by the Departments of Energy and Agriculture argued that emissions can be much lower than those coming from a petroleum-powered vehicle, with up to 78 percent less carbon dioxide. The CO₂ released from burned biodiesel can be recycled by growing plants. Nevertheless, use of the fuel burns hydrocarbons and contributes to greenhouse gases, albeit at much lower levels.

The use of government subsidies reduced biodiesel costs in the United States at one point such that costs were equivalent to gasoline. The U.S. Congress provided a retroactive reinstatement of a dollar-a-gallon credit in January 2013, amounting to about one-fourth of the fuel’s then current wholesale price. According to the National Biodiesel Board, production of the fuel has dramatically increased in recent years: from 2 million gallons in 2000 to 225 million in 2006 and more than 1 billion gallons in 2011.

Jason Hill and colleagues compared these two fuels in 2006, suggesting neither could “replace much petroleum without impacting food supplies.” They noted, “ethanol yields 25 percent more energy than the energy invested in production, whereas biodiesel yields 93 percent more.” Moreover, “relative to the fossil fuels they displace, greenhouse gas emissions are reduced 12 percent by the production and combustion of ethanol and 41 percent by biodiesel.” According to Wim Soetaert and Erick Vandamme, the production of vegetable oils cannot increase to meet the demand for biodiesel so competition with the food market is inevitable.

Jatropha is viewed by some observers as a very promising biofuel feedstock. *Jatropha curcas* L. (Barbados nut or pourghere plant) is a succulent plant originating in South America. The plant produces golf ball-sized nonedible, oil-rich seeds that are used mainly for medicinal purposes, to make soap, and as fuel for lamps. The jatropha bush produces a fruit containing a milky, yellowish liquid similar to that of palm oil, which can be used to make biodiesel.

Jatropha as an agrocrop for biodiesel production has attracted enormous attention in the last years especially after Goldman and Sachs proclaimed it to be one of the two most promising agrocrops. A British-based company has started an initiative to crop jatropha along train tracks in India, on mining-degraded land in the Philippines, and on a dumping ground for wastewater in Egypt.

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See Also: Air Pollution/Air Quality; Biodiesel; Biofuels; Ethanol; Gasoline, Reformulated; Green Fuels; Sustainable Transportation.

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Leonardo da Vinci made sketches of self-propelled wagons. A few centuries later, inventor Nicolas-Joseph Cugnot brought the dream to fruition with a steam-powered vehicle generally called the first automobile. This was followed by Karl Benz's development of the original gasoline-powered car, which used an internal combustion engine.

Benz's car served as the archetype for all internal combustion engine vehicles that came after it. His company, now known as Mercedes-Benz, went into production in Germany. Less than 15 years later, the Ford Motor Company was started in the United States and the era of the automobile had begun. Throughout the 20th century, additional car manufacturers started up in Europe, Asia, and the United States. The source of power for almost all of the vehicles produced remained the same: gasoline-powered internal combustion engines.

The Use of Fossil Fuels

Internal combustion engines get their name from their combustion of fossil fuels, specifically gasoline. Used efficiently, the process converts gas into mechanical energy, powering the vehicle. Unfortunately, the process also sends a substantial volume of polluting by-products out into the air through an exhaust pipe. In addition to carbon dioxide (CO₂) and water vapor, the by-products include carbon monoxide, benzene, and nitrogen oxide (NO_x). Sulfur dioxide (SO₂) may also be emitted due to gasoline impurities. These by-products adversely affect air quality by increasing smog, which particularly correlates to SO₂. Greenhouse gases like CO₂ also contribute to global warming. Nitrogen oxide is a factor in acid rain.

Because of these negative effects from using gasoline to power internal combustion engines, many people want to use alternative fuels for their cars and trucks instead. Their hope is that these will pollute less, helping protect the environment. There are many different kinds of alternative fuels that can be used to power automobiles.

Biodiesel

Some vehicles have compression ignition engines, also called diesel engines, which do not require a spark for ignition. They have a high rate of thermal efficiency compared to nondiesel internal combustion engines (ICEs). Because of that, they maximize the amount of mechanical energy that can be derived

Alternative Fuels

The idea of mechanical vehicles for roads once dominated by horses is an old one. It dates back to at least the 15th century, when famed artist

from a given amount of fuel. Typically, the rate of conversion is 45 percent. That contrasts to regular ICEs using gasoline, which only have a 30 percent conversion rate. Additionally, diesel engines using fossil fuels have only minimal CO₂ output in exhaust but do produce substantial amounts of nitrogen oxides when using fuel distilled from petroleum. That problem can be moderated by incorporating an alternative fuel called biodiesel.

Biodiesel is based on a lipid such as vegetable oil or tallow. Fatty acid esters are produced when the base substance is reacted with an alcohol, producing the mono-alkyl ester used for fuel. In standard diesel engines, biodiesel is not used exclusively. Instead, it is combined with petroleum-derived fuels in various percentages. For example, if the fuel used is 20 percent biodiesel and 80 percent sourced from petroleum, it would be labeled B20 (meaning biodiesel 20 percent). Using B100 (100 percent biodiesel with no petroleum-based constituents) can necessitate modifications to the diesel engine being used for the process to operate at peak efficiency.

Of course, higher percentages of biodiesel correlate to greater shares of the benefits this alternative fuel provides. One of those benefits is a decreased reliance on Middle Eastern sources of fossil fuels. That helps the United States become more energy independent and secure from the risk that geopolitical conflicts pose to fossil fuel supplies.

Another benefit is the lowering of greenhouse gas emissions, since use of vegetable oil based biodiesel is much less polluting than the use of fossil fuels. Because consumers have become more environmentally conscious over the past decade, lessening pollution is a major selling point to many.

Yet, using vegetable oil for this purpose is connected to a related debate about food versus fuel. The concern is that if too many farmers focus on raising crops that will be used in fuel production, they will raise less that are used for food. That dynamic can affect food supplies and raise prices. Fortunately, targeted crop production is not the only source of biodiesel.

Biodiesel fuel can also incorporate waste vegetable oil, also called UVO to indicate that it was already used for unrelated reasons. Industrial deep fryers typically found in food processing plants and restaurants produce 2.9 billion gallons of UVO per year. If recycled, it can be used in modified diesel engines as a fuel source. This option has gained substantial

publicity, as it makes use of waste material that might otherwise simply be disposed of. It also requires no additional use of farmable land, negating the objections directed at raising crops for fuel purposes.

Other sources of biodiesel include animal fat. While this also includes use of farmland, it is land that would be used for raising animals anyway. Those animals would typically be raised for meat, and the associated fat can be converted to fuel. Fish oil is an additional source, and it is derived from Omega-3 fatty acids production process.

An emerging source is called Salicornia. It is a salt-tolerant plant that can be grown in areas unsuitable for regular crops, including in marshes and even on beaches. It offers direct benefit to the areas in which it grows by filtering carbon dioxide from the air. Salicornia also produce seeds with a high concentration of unsaturated oil that is viable for biofuel purposes. This combination of traits is drawing substantial investment interest from around the world. Salicornia fields are the newest and potentially most promising biodiesel source, since the land in which they are grown would not support other crops anyway. With up to 250 gallons of fuel produced per hectare of Salicornia, it is a cost-effective, profitable, and environmentally responsible fuel source.

Ammonia

Another option currently being explored is ammonia, which is a gas composed of three parts hydrogen for every one part nitrogen. Tests have shown that it can be used in modified versions of internal combustion engines and diesel engines. This flexibility makes it an attractive possibility in that it could be used in current cars after modest alterations were made to their engine systems.

The approach with ammonia involves using it as a supplement to gasoline, allowing less gasoline to be used. First, a separate tank for the liquefied ammonia is added to a vehicle. The car is started with gasoline, and while the engine is idling, ammonia is added. This provides additional energy to the vehicle. Because ammonia has only half the energy of gas for equivalent volumes, vehicles equipped with these systems can switch back to using only gas when needed.

The combustion by-products of ammonia are simply water vapor and nitrogen. The absence of carbon-based pollutants, such as those emitted when using gasoline, is ammonia's major

selling point. In vehicles that use both fuels, there is an inverse relationship between them: the more ammonia used, the less gasoline used, resulting in less harmful exhaust.

Wood Gas

In World War II, the ramifications of war compromised oil and gas supplies for domestic consumers. By that point in history, however, the car had already become a staple of American life. Individuals still wanted to drive to their offices, homes, and shopping centers. Instead of giving up that desire, they came up with a very clever alternative.

Wood gas cars were built so people could get where they needed to go despite oil and gasoline shortages. They used the wood that otherwise would have gone into fireplaces to provide warmth.

The wood is placed in a wood gas generator, typically attached to the back of a vehicle. Putting it in the bed of a truck was common. Heat is used in the oxygen-limited environment of the generator, producing gases that can be used to power vehicles. Since wood was in plentiful supply at affordable prices, it seemed like a great idea.

That turned out to be accurate. The wood gas cars worked very well and wound up being the most successful experiment with alternative fuels to that point in time. They were not only popular in America but could be found in every part of Europe as well. Thousands of refueling stations were established so drivers of these vehicles could purchase and use additional firewood. It was a complete alternative fuel distribution system, and one that was adeptly managed for the benefit of commuters.

After the war, as oil and gas again became more available to civilians and were more convenient to use, the wood gas cars faded into obscurity. They were all but forgotten until recently, when interest was reawakened by modern environmental concerns and rising oil prices. Now, many people are viewing this alternative fuel of the past as a viable energy source for the future.

Hydrogen

One of the most talked-about alternative fuels for motor vehicles is hydrogen. Major car manufacturers are developing cars powered by fuel cells, with early models commercially available by 2013. There is even a World Hydrogen Energy Conference held

biannually, which focuses on uses for hydrogen energy that include powering vehicles.

Fuel cells for cars are used in stacks (multiple fuel cells for each vehicle). This is so that their overall energy production will be sufficient to power the vehicle. The fuel cells use catalysts to convert hydrogen gas into electrons that are negatively charged and ions that are positively charged. The flow of the electrons is employed as electricity to power the car. Meanwhile, the ions (H^+) harmlessly combine with oxygen (O_2) to produce water (H_2O). This enables the car to get the electrical energy it needs, and the sole by-product of the process is water. There are none of the greenhouse gases and other pollutants associated with fossil fuels. Naturally, this makes vehicles powered by hydrogen fuel cells very attractive to environmentally conscious consumers. It is also a major reason why hydrogen is likely to be at the forefront of alternative energy sources for decades to come.

One of the challenges to mass-producing fuel cell vehicles (FCVs) so far has been storing the hydrogen. To this point, the primary method has involved keeping it in high-pressure tanks at 5,000 to 10,000 PSI (pounds of pressure per square inch). The tanks are expensive and heavy. Automotive companies are working to reduce the size and weight to make the tanks more viable for regular use.

A different storage possibility is being explored: condensing the space needed for the hydrogen by keeping it in its more dense liquid form. Of course, doing so requires additional energy expenditure, providing another cost issue to be addressed.

Aside from storage, a key question with hydrogen is its source. If it is taken from methane, coal, or gas, the production process will create pollutants and compromise the environmental goals of hydrogen fuel advocates. Unfortunately, fossil fuels are the primary source used in the \$100 billion industry of hydrogen production, most of which is targeted to industrial use.

However, there are more environmentally friendly ways to secure large amounts of hydrogen. One important method is called fermentative hydrogen production. It uses green algae or cyanobacteria, depending on the version of the process. These tiny life forms feed on carbon-based organic substrate and exhale a combination of hydrogen and carbon dioxide. The carbon dioxide is separated out, leaving the hydrogen available as an

alternative fuel for human uses like powering cars. This is a process that routinely occurs in nature, and it is being repeated in labs as consumer demands for hydrogen energy grow.

Air

As remarkable as it sounds, using air to power vehicles is a viable option. In fact, it has been done on a limited basis for years. The process is a simple one: an air compressor takes in air and compresses it. Next, it is transferred to a vehicle's compressed air tank. This can be a lengthy process that might take hours for a typical car. Once done, the car sends the compressed air into the engine as needed. There, as the air again expands, it releases energy that powers the car. There are no by-products from the process, and thus there is no pollution. Correspondingly, the usage of compressed air does not contribute to global warming or other environmental problems. Additionally, air is free and the compression process is inexpensive. Drivers who use it will be insulated from the rising prices of fossil fuels.

If air cars become prevalent, service stations will undoubtedly maintain supplies of precompressed air, making the transfer process much faster. With the right equipment, the stations will be able to provide this alternative energy source to travelers with air cars on a regular basis.

Electric Car Power Sources

Electric cars are free of harmful emissions, giving them an environmental advantage. They also run smoothly and quietly. For these reasons, using electricity to power vehicles is a great option. The overall environmental impact they have depends on the original source of their electricity.

Solar and wind. Both wind and solar power can be used to produce electricity, and that electricity is then distributed as an energy source for a variety of needs, including powering vehicles. This makes it an indirect alternative energy source for transportation, but still a valuable one. Because they provide cheap and renewable power for electric cars, wind and solar power have gained value as alternative energy sources.

Solar energy comes from the sun. When companies and individuals want to collect that energy in the form of electricity, they set out an array of photovoltaic panels. "Photo" refers to light (in this case,

sunlight) and "voltaic" refers to the production of energy, specifically, electricity. They are also called solar panels. The panels convert the sun's light energy into electricity with silicon semiconductors. The process frees electrons, which are redirected as a current. The current, in turn, can be used to power electric cars.

When owners of solar-powered cars want to ensure that their electricity source is clean solar power, they have two options. The first is to install their own solar panels on their property and collect the electricity produced for use in their vehicle. The second is to buy electricity from a supplier who gets it from their own array of solar panels. Either way, it is an effective means to power a car without producing any of the harmful emissions associated with fossil fuels.

In the case of wind power, it is unlikely to be produced in quantity at a family home, short of living



Salicornia growing near Southampton in the United Kingdom. Salicornia fields can yield up to 250 gallons of fuel per hectare, making the plant one of the most promising biofuel feedstocks.

on an extremely windy mountainside. However, owners of electric cars can still source their electricity to wind by purchasing it from a major producer. There are power companies that make their records available, showing how much they use alternative energy sources, including wind. That information can be obtained by simply calling local power companies and asking for it.

Wind power is typically produced en masse, with hundreds of wind turbines composing what is called a wind farm. Each of those wind farms connects to the local power transmission network, allowing the kinetic energy of wind-powered turbines to be converted to electricity for everyday use. Like solar power, wind power is a nonpolluting process with no dependence on fossil fuels. When this energy is used to power electric cars, it further contributes to the reduction of greenhouse gas emissions.

Wind farms can be on land or offshore, though cost considerations for ocean-based wind farms can be prohibitive. Wind is classified as a renewable power source, and the farms can be placed in areas unsuitable for agriculture, circumventing “food versus fuel” debates.

As a form of purely mechanical power, wind has been used for thousands of years. On a small scale, it can be traced back to ancient Greece. On a large scale, it has been employed through windmills for at least 11 centuries. Windmills famously use this mechanical power to grind flour and to operate pumps for agricultural purposes.

The first known instance of using wind to generate electricity was in 1887, when a professor named James Blyth was able to use wind turbines to power his lights at home. Other inventors quickly followed suit. Included among them was Poul la Cour, a Danish scientist who used electricity from wind energy to power electrolysis. The electrolysis separated water into oxygen and hydrogen. Since hydrogen is another sought-after alternative energy source used to fuel cars, Poul la Cour can be viewed as one of the premier alternative fuel pioneers.

Water. Sourcing power for electric cars from water is another viable option. Water, like wind, offers natural kinetic energy by its motion from one place to another. That motion—again, like wind—represents a renewable energy source, and a clean one free of polluting by-products.

In the 19th century, water started to be used as the energy source for hydroelectric plants. Typically associated with dams on rivers, these plants were also put in other areas with high volumes of water in motion. A famous example is close to Niagara Falls on the U.S.–Canada border.

Currently, over 3,400 terawatt hours of hydroelectricity are generated each year worldwide, making it the most widely used form of alternative energy on Earth. When electric car owners source the power they use to water, they know that the production process is free of pollutants.

Looking Forward

Internal combustion engines that use gasoline are still the standard. Yet, with 1.7 billion cars projected to be on the road by 2035, the emissions from those cars will become of progressively greater concern. The 21st century to date has been defined by increasing environmental awareness, as consumers become better informed about the causes of global warming, acid rain, smog, and other types of environmental damage that harm human health. While efforts to reduce personal energy use will continue, demands for energy from individuals and industry are likely to increase over the ensuing decades.

One reason for that increase by individuals is that new innovations are invented every year. Drivers want every new convenience and gadget, from improved air conditioning and sound systems to customizable in-vehicle computers. Many also want larger vehicles for the sake of comfort and safety. All of these factors together result in higher energy demands for each vehicle.

Industries continue to produce new products, requiring massive amounts of energy and fuel on a global scale to transport larger amounts of raw materials to factories, to manufacture products, and to get finished goods to markets.

These needs will grow further as the world population increases. As of 2011, it was already at 6.974 billion people worldwide. According to United Nations projections, it will be approximately 9.1 billion by 2050. That increase of 2 billion people will mean more individuals driving on the roads and more vehicles in commercial use to bring them goods and services. If all of that energy use continues to center primarily on the burning of fossil fuels, multiple current problems will be accentuated.

One problem is the reliance of Western countries on the Middle East for fossil fuels. This reliance means that the energy needs of the United States and other countries are continually in jeopardy. This jeopardy arises from the fact that instability in the Middle East can compromise fossil fuel supplies at any time. Prices can also spike at any time, resulting in added expense and potential shortages.

Another problem will be an intensifying of the greenhouse effect, as greater amounts of carbon dioxide are emitted in the exhaust of vehicles. This corresponds to rising global temperatures, which adversely affect farmable land and cause sea levels to rise. Global warming has also been implicated in the melting of glaciers and atmospheric disturbances caused by higher ocean temperatures. Those disturbances may adversely affect weather conditions, though a scientific consensus on that is still pending.

An additional environmental effect of unabated fossil fuel use in vehicles will be decreased air quality. Cities like Los Angeles that have many cars and trucks on the roads deal with problems like smog, which manifests as a toxic brown cloud over what should be a pristine coastline. Los Angeles has even had to issue alerts to residents about particularly unhealthy ozone levels, in order to warn them about being outdoors on days of heavy smog. This has been viewed by many as an indicator that air pollution has reached a crisis level.

Naturally, people across the country are concerned about these effects, knowing that they can be visited upon even rural areas in time as traffic increases. After all, as populations grow, urban centers expand, bringing more roads and cars. Thus, there is an eagerness to do something about the problem of polluting emissions from fossil fuel-based vehicles. That eagerness will continue to center on the development and use of alternative fuels. Key among alternative energy sources for transportation will be those discussed above: biodiesel, ammonia, wood gas, hydrogen, solar, wind, and water.

For alternative fuels to be accepted, their environmental benefits will need to be more widely publicized. The more consumers are aware of how alternative energy sources can reduce harmful emissions, the better. Surveys show that most people care about protecting air and water from pollution but

need more information on clean alternative energy sources. Specifically, they need to know how these energy sources work and how they can be used to power vehicles. Environmental organizations and governments are working to provide greater dissemination of that information. Widespread events like Earth Day present a venue to educate the public about these issues. The U.S. Environmental Protection Agency (EPA) also makes available detailed information via its Web site.

Successful acceptance of alternative fuels will also require cost-effectiveness. Consumers want to feel confident that their energy costs will stay the same or decrease as they shift toward alternative sources. Even the most environmentally conscious consumer hesitates if cost is a significant issue, so bringing down costs is expected to have a major effect.

One way to pursue that cost-effectiveness is by using materials and processes that would otherwise go to waste. Used vegetable oil, discussed above, is one good example. When fast food restaurants soak the foods they serve in oil by deep frying, "waste oil" is a by-product. In the past, that excess vegetable oil was disposed of, wasting a potential resource. Millions of gallons would be wasted each year. Thanks to entrepreneurial resourcefulness and growing consumer needs, that by-product is now being constructively used as an energy source.

Salicornia, also discussed above, provides another emerging approach to the development of alternative fuels for vehicles. By using land that other crops cannot prosper on, it circumvents the food versus fuel debate that has hobbled ethanol production in some areas. At the same time, it serves as a rich resource for plant-based oils that can power cars without harmful emissions.

As consumer demand for these alternative fuel sources grows, they will be progressively more attractive to investors. In turn, the capital supplied by these investors will spur new ways to maximize the efficiency of alternative energy production. Costs will come down, and distribution will correspondingly expand. With all these factors in play, the future for alternative fuels looks bright. In time, clean energy for motor vehicles will no longer merely be an alternative: instead, it will be the new standard.

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See Also: Alternative Automotive Fuels; Alternative Motor Fuels Act of 1988; Automobile Engines; Biodiesel; Biofuels; Carbon Dioxide Emissions; Climate Change, Transportation Adaption to; Diesel Engines; Electric Vehicles; Environmental Impacts; Gasoline Engines; Green Fuels; Hydrogen Fuel; Liquefied and Compressed Natural Gas.

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Alternative Motor Fuels Act of 1988

The Alternative Motor Fuels Act of 1988 (Public Law 100-494), commonly designated as AMFA, was designed to clean up the environment and reduce American dependence on foreign oil by rewarding automobile manufacturers who produced vehicles that could run on alternative fuels, such as methanol, ethanol, and natural gas. The bill also included an \$18 million appropriation for the Department of Energy (DOE) to set up commercial demonstrations of vehicles that operated on alternative fuels. Other stipulations involved a mandated DOE study of methanol production plants and a mandated Department of Transportation (DOT)/Environmental Protection Agency (EPA) study of environmental impacts of alternative fuels. The bill also created the Interagency

Commission on Alternative Motor Fuels to coordinate alternative fuels policies and studies and established the U.S. Alternative Fuels Council, an investigatory group comprising four members of Congress and 16 individuals chosen by the inter-agency commission. Both the commission and the council were terminated in 1992 upon final submission of their reports.

Other provisions of the bill paved the way for the creation of the Alternative Fuels and Advanced Vehicles Data Center, which was established in 1991 under the auspices of the Department of Energy's National Renewable Energy Laboratory. Subsequent analysis of the impact of AMFA has produced mixed results; most American cars continue to run on gasoline rather than on alternative fuels, and the dependence on foreign oil continues.

Background

The push for alternative fuels accelerated in the 1980s as the environmental movement gained momentum in conjunction with the increased push to reduce dependence on foreign oil. The most highly touted form of alternative fuel was methanol, which was made from natural gas. At the time, the United States was able to fulfill 95 percent of domestic requirements for natural gas, and the remaining 5 percent was imported from Canada rather than the Middle East or Eastern Europe. In 1987, both Ford and General Motors introduced cars that ran on methanol, ethanol, gasoline, or some combination of the three within a single tank.

As vice president, George H. W. Bush chaired a White House task force that paved the way for the passage of the Alternative Motor Fuels Act of 1988. The legislation (S. 1518) was introduced by Senator Jay Rockefeller (D-WV), who had been working on passage of an alternative fuels bill since 1985. By December 1987, the House of Representatives was leaning toward mandating the use of 10 percent ethanol in all motor fuels.

As an economic incentive, both the House and the Senate were willing to grant mileage credit to any manufacturer who produced vehicles capable of running on alternative fuels. A conference committee was charged with working out the difference between S. 1518 and the House version (H.R. 8399). After five months of negotiation, the conference committee finally agreed on an alternative fuels bill.

President Ronald Reagan signed the Alternative Motor Fuels Act of 1988 into law on October 14, 1988. The final version granted manufacturers who produced vehicles operating on alternative fuels or those who manufactured vehicles that could run on either alternative fuel or gasoline credits toward meeting Corporate Average Fuel Economy (CAFE) ratings beginning in 1993.

Impacts

As congressional support mounted for passage of the act, public opposition consisted of an unusual coalition of environmentalists, oil company officials, and concerned citizens. Even those who supported the use of alternative fuels frequently objected to mandating the use of such fuels. The most frequent argument against passage of AMFA was that both the economic and environmental impact of widespread use of alternative fuels was far from certain.

Oil companies were predictably concerned about additional government regulation. American farmers were concerned about the possible impact on farm subsidies if corn surpluses were directed toward ethanol production. Environmentalists and consumer protection advocates argued that inflating the mileage of vehicles operating on methanol would end up allowing other vehicles to become less fuel efficient, resulting in additional environmental damage and higher operating costs for consumers.

In late 1988, following passage of the Alternative Motor Fuels Act, states began working with automobile manufacturers to create environmentally friendly fleets for government use. California had been an innovator in the area of alternative fuels for over a decade and had established its own alternative fuels program in 1977. After passage of AMFA, the California Energy Commission formed a partnership with General Motors to provide the state with 2,220 alternative-fuel demonstration vehicles capable of running a blend of 85 percent ethanol and 15 percent gasoline (E85). At the same time, ethanol pumps were placed in strategic locations in California. The California legislature had already passed legislation promoting the use of alternative fuels in both private and public transportation, encouraging ridesharing, and replacing energy-inefficient school buses with newer, cleaner models.

In March 2002, a joint report submitted to Congress by the Department of Transportation, the Department of Energy, and the Environmental Protection Agency stated that the impact of the Alternative Motor Fuels Act of 1988 had been mixed. While AMFA had indeed increased the availability of alternative fuels and motivated automobile manufacturers to produce more environmentally friendly vehicles, those running on gasoline continued to be the norm. At that time, there were only 5,236 alternative refueling sites, compared to 176,000 gas stations. Furthermore, only 121 alternative refueling sites offered the ideal E85 mix of 85 percent ethanol and 15 percent gasoline. The price of alternative fuel in comparison to gasoline had proved a deterrent, and many vehicle owners continued to use gasoline in cars capable of running either type of fuel.

Incentives included in AMFA were extended in 2004 when Congress enacted the Automotive Fuel Economy Manufacturing Incentives for Alternative Fueled Vehicles Rule. The following year, Congress passed the Renewable Fuels Standard, and the number of ethanol stations began to increase in the United States.

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See Also: Air Pollution/Air Quality; Alternative Automotive Fuels; Environmental Impacts; Vehicle Emissions Standards.

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American Association of State Highway Transportation Officials

The American Association of State Highway Transportation Officials (AASHTO) was established in 1984 as a means of fostering the “development, operation, and maintenance of an integrated national transportation system” within the context of the American system of federalism, which shares certain powers between national and state governments.

Headquartered in Washington, D.C., AASHTO comprises representatives of highway and transportation departments from all 50 of the United States and from Washington, D.C., and Puerto Rico. The nonprofit organization is nonpartisan. In addition to providing advice and technical knowledge to its members, AASHTO develops transportation policy and establishes technical standards in transportation.

The group also serves as a link between state departments of transportation and the U.S. Department of Transportation. Designed to represent the interests of the entire transportation sector, AASHTO deals with issues that are of concern within the fields of aviation, highways, public transportation, railways, and waterways. AASHTO electronically publishes the *AASHTO Journal* each Friday and also delivers a free newsletter via e-mail. Additionally, AASHTO publishes *AASHTO Quarterly* (previously known as *American Highway and Transportation Magazine*).

Organization

The heads of all state departments of transportation serve on AASHTO’s board of directors. An executive director works with the 12 elected members of the executive committee to provide leadership to the group. The various committees that carry on the day-to-day activities of AASHTO are made up of volunteers from state transportation departments who are experts in their fields. Their expertise comes into play when carrying out the ongoing work of standing committees, which include aviation, environment, finance and administration, highway traffic safety, highways, performance management, planning, public

transportation, rail transportation, research, and water transportation.

Some standing committees are divided into area-specific subcommittees. The Standing Committee on Finance and Administration, for instance, has eight subcommittees: civil rights, fiscal management and accounting, information systems, internal and external audit, personnel and human resources, TRAC (transportation and civil engineering), transportation communications, and transportation finance policy.

Special committees are created as the need arises. In 2013, for example, special committees included those on intermodal transportation and economic expansion, joint development, transportation security, and emergency management. The work of the census transportation planning products program (CTPP) is also carried out by a committee, which works with states to gather census data that impact the transportation sector.

Programs

Many of AASHTO’s programs are involved with establishing standards, issuing accreditations, and awarding innovation in transportation technologies. The Technology Implementation group, for instance, champions technologies that are deemed to have a major impact on the transportation sector in fields such as construction, design, the environment, maintenance, safety, and traffic. One recent award-winning technology was the Sequential Flashing Warning Lights for Work Zones system that was designed to improve safety in work zones, guiding motorists through merge tapers at a cost of only \$100 to \$110 per unit.

Another award-winning technology involves the use of Environmental Planning GIS Tools, such as mapping technology to analyze the ways in which the environment is affected by transportation activities. Construction analysis software tools (CAST) also won recognition from AASHTO for the technology’s ability to cut down on traffic congestion while maximizing safe mobility at construction sites.

Outreach

Outreach is a major element in the work carried out by AASHTO, which works with teachers in the fields of science, technology, engineering, and math (STEM) to promote interest in pursuing

careers in transportation and civil engineering. At the elementary level, the Roads into Development in Elementary Students (RIDES) program is a joint project carried out by AASHTO and the Mississippi Department of Transportation. Geared for K–8 students, activities are designed to encourage interest in science, technology, engineering, and math in age-appropriate ways.

In addition to the work done by the organization, members from individual state departments of transportation work with local school systems to develop STEM curricula. Students working on AASHTO modules become engaged in solving real-life transportation problems while carrying out such activities as designing cities and building bridges.

At the elementary level, the Roads Into Development in Elementary Students (RIDES) program is a joint project carried out by AASHTO and the Mississippi Department of Transportation. Geared for K–8 students, activities are designed to encourage interest in science, technology, engineering, and math in age-appropriate ways.

Pool-Funded Projects

AASHTO is also involved in a number of projects in which interested parties from federal, state, and regional agencies work with academic institutions and the private sector to fund and conduct research in particular areas that affect transportation in the United States.

Pool-funded programs include AASHTO Innovative Highway Technologies (LEAD States Program), AASHTO Product Evaluation Listing (APEL), AASHTO Technology Implementation Group, the Climate Change Technical Assistance Program, Joint Development Software Products (AASHTOWare), the Multi-State Technical Assistance Program (MTAP), the National Transportation Product Evaluation Program (NTPEP), Radio Frequency Coordination Procedures and Fee Schedule 511 Implementation, SHRP Product Implementation, and the Snow and Ice Cooperative Program (SICOP). Involvement in such groups occurs according to the discretion of individual state departments of transportation.

Work accomplished by these projects has major implications for the transportation sector, affecting such areas as policy formation, program planning, and budgeting. For instance, the Transportation

and Climate Change Resource Center provides information and services and serves as a resource center for state transportation departments dealing with environmental issues. Policy recommendations are developed by the Climate Change Steering Committee, which works with the Climate Change Technical Assistance Program to help state departments of transportation carry out activities intended to mitigate negative impacts of climate change. AASHTOWare uses professionals to create software that meets the needs of its members. Its software assists state departments of transportation to create budgets, design reports, deal with federal agencies, and work with state officials over time.

Through pool funding, AASHTO is also involved with the National Cooperative Highway Research Program, which was established in 1962. This program conducts research in critical areas such as constructing interstate highways, building bridges, making transportation safer, and protecting the environment in the course of carrying out transportation-related activities.

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See Also: Automated Traffic Control Systems; Highway Planning; Interstate Highway System; State Highway Planning and Finance; U.S. Department of Transportation.

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American Public Transportation Association

The American Public Transportation Association (APTA) is a nonprofit advocacy membership organization that promotes policies, programs, and laws supportive of public transportation in North America. Headquartered in Washington, D.C., APTA's vision statement is to "Be the leading force in advancing public transportation." Its mission, the organization states, is to serve and lead its "diverse membership through advocacy, innovation, and information sharing to strengthen and expand public transportation."

History

Founded in 1882, APTA was originally known as the American Street Railway Association, a membership-based organization of 56 transit companies from across the United States. Beginning in the early 1900s and continuing until the 1940s, predecessors of APTA were the only organizations compiling and publishing data on public transportation in the United States. As the sole source of comparative data on transit administrative, performance, and financial operations, APTA's predecessors became crucially important for researchers and practitioners in the early to mid-1900s. The organization saw a series of name changes, including names like the American Transit Association and the American Public Transit Association before settling on the American Public Transportation Association in 2001. Two other organizations merged with predecessors of APTA—the Institute for Rapid Transit in 1974 and the High Speed Ground Transportation Association in 2007. The group is known for its annual *Public Transportation Fact Book*, which it has compiled since 1943.

As the complexity and regulatory oversight of transit operations expanded alongside government funding in the 1960s, APTA and its predecessors assisted individual transit agencies with reporting requirements, grant applications, and operating assistance, and it continues to do so.

Membership

Beginning with 56 member transit agencies in 1882, the APTA in 2012 comprised over 1,500 member

organizations, growing from 1,270 members in 2000, including groups like transit agencies, engineering firms, universities, and state departments of transportation, among others. According to testimony provided to the U.S. House Appropriations Committee in 2000, 90 percent of public transportation users in the United States and Canada are served by agencies that belong to APTA, reflecting the organization's broad membership base.

Advocacy

The APTA seeks to provide a unified voice for transit agencies and public transportation proponents that both educates the general public and lobbies Congress and state and local policy makers on matters relevant to the interests of mass transit. Seeing its primary roles as advocacy, transportation innovation, and information sharing, APTA releases dozens of white papers each year on topics related to transportation (for example, high-speed rail, poverty, aging, and sustainability) and maintains an active media presence for an organization its size.

Between 1997 and 2012, the organization and its employees donated over \$60,000 to various members of Congress (76 percent of the donations were to Democrats, 24 percent to Republicans). More significantly, as of 2012 the organization employed 10 lobbyists, having spent just under \$20 million to influence policies impactful to public transportation.

APTA also maintains a charitable foundation, the American Public Transportation Foundation, which provides and administers 11 scholarships to students and individuals seeking careers in public transportation. Scholarship recipients must be sponsored by a member of the APTA.

Conferences and Meetings

APTA hosts an annual meeting of its members, which it bills as the primary conference for the transit industry as a whole, with speakers, roundtables, and forums on issues of importance to the organization's membership. In addition, APTA hosts smaller workshops and conferences on niche issues affecting public transportation, such as sustainability, disability access, and multimodal operations. Every three years, the APTA hosts the APTA Expo, a trade show for member organizations to showcase technology, products, and services.

Publications

APTA's most widely known publication is the annual *Public Transportation Fact Book*, a resource compiling hundreds of data points for comparison across the industry, which the organization has published since 1943 and does not copyright. The *Fact Book* not only compiles data from individual transit agencies but also sums the data points across metropolitan areas, providing at-a-glance statistics for all forms of public transportation regardless of provider agency in urbanized regions.

In addition to the *Fact Book*, APTA also publishes an online "Buyer's Guide," a biweekly magazine called *Passenger Transport*, white papers on issues of interest to public transportation organizations, and an online resource library for what it calls "Hot Topics" in public transportation.

Governance

The most senior position at APTA is the president and chief executive officer (CEO), followed by seven vice presidents overseeing specific areas of the organization's administration. The president/CEO is accountable to APTA's board of directors, which is chosen through both elections of the membership and appointments by specific APTA members. There are 104 members of the board of directors. Because the board's size prevents frequent meetings, APTA also utilizes an 18-member executive committee, also elected by the APTA members, which is authorized to act on behalf of the board of directors.

APTA also convenes dozens of committees and task forces that address specific areas of importance to member organizations.

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See Also: Federal Transit Administration; Social Equity and Discrimination in Transportation; Transit Systems; Transportation Statistics and Databases.

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Americans with Disabilities Act of 1990

Passed by the U.S. Congress in 1990 to address the long-term restrictions on the civil rights of Americans with disabilities, the Americans with Disabilities Act (ADA) has affected many aspects of the nation's commercial, community, and public interactions, including those dealing with transportation. Like the Civil Rights Act of 1964, which prohibited discrimination based on national origin, race, religion, sex, or other characteristics, the ADA offers legal protections to disabled Americans. As the ADA expanded conceptions of "disability" to include any physical or mental impairment that limits major life activities in a substantial way, the act greatly expanded how those involved with transportation serve those with disabilities. Public transportation, whether provided by commercial entities or government agencies, must comply with regulations set forth to assure compliance with the ADA. Failure to do so opens transportation providers up to charges of discrimination.

Background

Though the civil rights of individuals were in theory always protected by the U.S. Constitution, it was not until the civil rights movement began to achieve victories in the 1950s and 1960s that individuals from certain ethnic and racial groups and members of certain religions began to have recourse to overt discrimination. During the 1970s, the civil rights of women increasingly began to be examined and protected, as legislation was passed that was intended to prevent discrimination based upon sex. In keeping with this view, the rights of the disabled to be able to access education and other training were progressively expanded. As a result of this examination, in 1975 Congress passed the Education for All Handicapped Children Act (EAHCA), which sought to increase access to public education for children with disabilities. EAHCA, later

reauthorized as the Individuals with Disabilities Education Act (IDEA), only applied to those school districts and government agencies that accept federal funding, but it does require that children with disabilities be provided educational and other services to best meet their needs. This legislation, in conjunction with the Rehabilitation Act of 1973, which mandated that reasonable accommodations be made for those with disabilities by employers, schools, and various others, greatly expanded the civil rights of the disabled.

Throughout the 1980s, the increasing visibility of the disabled in educational and other settings increased expectations among their advocates for more and better opportunities for this group. To that end, calls grew for legislation that would protect the rights of individuals with disabilities in a manner that would better ensure their rights to participate in society. Sponsors of the ADA forged a variety of alliances over the 1980s as they grew closer to their goal of achieving global and comprehensive protection for those with disabilities. With the passage of the ADA, a new assortment of civil rights, and a variety of avenues through which to pursue these, was accorded to individuals with disabilities. In addition to transportation, the ADA addressed the rights of the disabled with regard to employment, benefits, and services provided by state and federal government agencies, public accommodations, and telecommunications relay services.

Reaction to and Scope of the ADA

Designed to be comprehensive in nature, and passed with broad bipartisan support, the ADA was signed into law by President George H. W. Bush on July 26, 1990. Passing the House of Representatives by a vote of 377–28 and the Senate by 91–6, the ADA had faced significant opposition, including from those who believed its implementation would be too expensive.

Many advocates for business interests, including those in the transportation sector, also opposed the ADA's passage. For example, Greyhound Bus Lines, an intercity carrier of passengers, had suggested during hearings on the act that its passage would cause the cancellation of multiple routes, denying many urban and rural communities their most cost-efficient link to travel to other areas. Small business owners in particular felt that the provisions of the ADA would negatively affect their profitability,

especially in light of economic problems already facing the nation. Despite these criticisms, supporters of the ADA emphasized that the legislation would make it easier for businesses and society to access the critical talent pool that the disabled represented. By forcing the United States to become more inclusive, it was argued, a host of employment opportunities would be opened for individuals with disabilities that would permit many more to be self-sufficient and independent.

The ADA provides wide-ranging civil rights protections to individuals with disabilities, prohibiting discrimination based on physical or mental impairments that would otherwise substantially limit major life activities. Determinations regarding whether a specific condition is considered a disability are made on an individual basis.

Comprising five titles, the ADA deals with employment, public entities (including transportation), public accommodations (including commercial buildings), and telecommunications, and also contains miscellaneous provisions regarding the act's implementation and interaction with other legislation. With regard to employment, as covered by Title I of the act, the ADA covers employment agencies, labor organizations, or other employers who have 15 or more workers. The ADA requires employers and other entities to make reasonable accommodations for the disabled and prevents the use of medical examinations unless these are used for all applicants and treated in a confidential manner. Title III of the ADA, covering public accommodations and commercial facilities, requires business owners, operators of hotels and restaurants, recreation providers, and others to ensure that all new construction, alterations, or remodeling efforts remove barriers to the disabled.

The costs of modifications are to be balanced against the potential hindrance to the disabled, thereby requiring larger concerns to spend more than small businesses. Telecommunications companies, governed by Title IV of the ADA, must take steps to ensure that their products and services are available to the disabled, which sometimes requires the provision of equivalent services for those who are deaf, hard of hearing, or who struggle with speech impairments. Title V deals with miscellaneous provisions of the act, and makes clear that nothing in the ADA overrules provisions in the Rehabilitation Act of 1973 or IDEA.

The ADA and Transportation

In addition to prohibiting discrimination against individuals with disabilities by school districts, municipalities, counties, and state agencies, Title II of the ADA requires public transportation to be accessible to the disabled. Public transportation covers a wide variety of services, including city bus lines and public rail transit, such as subways, light rail, commuter lines, and Amtrak. While Title II applies only to public entities, private carriers, such as airlines and intercity bus carriers, are also covered through Title III. The ADA requires public and private carriers to remanufacture buses, trains, and other vehicles in a way that will make these accessible, and to purchase only new stock that complies with the act and the need for this stock to be accessible. Public authorities must also provide paratransit, a service for individuals unable to use regular transit as a result of mental or physical disabilities. Paratransit provides the disabled with door-to-door service, whereby they are picked up at their homes and dropped off at their specific destinations. The ADA prohibits discrimination against disabled persons and mandates that common carriers make accommodations that permit them to serve such individuals.

At the time of the ADA's passage, the overall labor force participation rate was 78 percent, while that of the disabled labor force was only about 33 percent. Part of this disparity was believed to be caused by the paucity of options available to individuals with disabilities for access to transportation that would permit them to travel to job opportunities. The charge for transportation agencies and other providers of public travel options to remove barriers to people with disabilities was often linked to the need for these individuals to go to work and other places that would enable them to better their life options. Although there was a certain amount of initial resistance to the ADA by transportation carriers, the need for the disabled to travel to and from work ultimately proved persuasive and compelling.

Traditionally, analyses of providing transportation services to the disabled focused upon the incremental costs of accessible options. In 1989, the Urban Mass Transit Administration (UMTA), now the Federal Transit Administration (FTA), examined the costs of compliance with the accessibility rules contained in the ADA. At that time, the FTA estimated the costs of compliance with



These Metrolink transit, bus, and Amtrak ticket vending machines in Santa Clarita, California, are two different heights because the machine at right is at an Americans with Disabilities Act–compliant height accessible to people using wheelchairs.

the ADA's requirements to range from \$850 million to \$1.3 billion annually, which was a sum greater than the \$8.8 to \$13.6 billion estimated by the Congressional Budget Office as needed for conformity with these requirements over a 30-year period. The costs estimated by the FTA totaled approximately 5 percent of annual transit budgets, which was the basis of the industry's resistance to the ADA. Rather than focusing on individuals with disabilities as customers with special needs, the disabled were marginalized as a "cost category." As long as the focus of transit professionals centered on costs, especially vis-à-vis other passengers, resistance to the ADA persisted.

Over the past years, however, changes in how transit agencies operate have made it easier for accommodations to be made that directly benefit the disabled. Since 1980, the number of transit trips taken annually has remained fairly stable each year, with approximately 8 billion passengers annually making use of such services. In constant dollars, the national transit budget has also remained fairly

stable, although these numbers have increased slightly since 2009. Despite this apparent stability, a great deal of change has taken place. The proportion of transit miles traveled on commuter rail, light rail, and rapid rail has grown substantially, surpassing miles traveled on transit buses. Indeed, transit bus services and passengers have declined as lower income families became more likely to own one or more automobiles. As new railcars and buses have been purchased, transit authorities have ensured that these comply with the ADA. Litigation has also made clear that courts interpret the ADA as being charged with making existing transit opportunities available to all riders, not mandating the requirement of new transit services. Despite this, many transit agencies have elected to provide paratransit as a lower cost alternative to making the modifications necessary to their existing stock.

ADA Standards for Accessible Design

In 2010, the U.S. Department of Justice promulgated new ADA Standards for Accessible Design, replacing those first released shortly after the act was passed in 1990. The ADA Standards for Accessible Design affect more than 80,000 local, state, and federal governmental agencies and facilities as well as over 7 million privately owned businesses. The more than 54 million Americans with disabilities will benefit from these standards in that new construction, or modifications to existing construction, will have to comply with the standards, which in turn will provide a variety of new opportunities to those whose movements were impeded by barriers to their mobility. The U.S. Departments of Justice and Transportation are primarily charged with implementation of the ADA Standards for Accessible Design, although a variety of federal agencies have some responsibility for their enforcement.

The new ADA Standards for Accessible Design, which took effect in 2012, affect transportation in a variety of ways. All airport terminals, train stations, or other transit facilities must contain elevators when alterations are made to existing buildings or when new structures are erected. Certain minimum widths are established by the ADA Standards for Accessible Design for doorways, corridors, and other passages so that wheelchairs and other devices may be used by the disabled. The responsibility for demonstrating that an equivalent facilitation for the disabled, in the event of a challenge, rests with

the transit authority, making it necessary for most building and remodeling projects to include input from advocacy groups for the disabled from early stages of new projects. Criteria are set forth within the standards that control the construction, design, inspection, installation, maintenance, operation, repair, and testing of lifts used to transport the disabled.

Alterations or construction affecting the functioning of facilities must consider more than just accessibility for individuals with disabilities. Services and amenities in the area, such as drinking fountains, restrooms, telephones, and the like must also be usable by individuals with disabilities unless such modifications are cost prohibitive. At least one accessible route throughout airports, rail terminals, and other transit facilities must be provided so that access is available to disabled individuals from handicapped parking spaces and loading zones.

Remedies Pursuant to the ADA

The ADA provides individuals with disabilities whose civil rights have been violated with access to a variety of remedies. The ADA permits private parties to receive only injunctive relief, such as court orders requiring transportation authorities to provide remediation to address accessibility deficiencies, as well as attorney's fees. Unless applicable state law provides for monetary damages, the disabled may not obtain direct financial benefits for pursuing violations of the ADA. This being the case, significant changes have taken place regarding impediments to transportation as a result of private actions. For example, online travel marketers were forced to modify booking practices on their Web sites to reduce the efforts required by customers with disabilities to research accessible hotel rooms. Additionally, cruise ships flying the flags of foreign nations were determined to be under the purview of the ADA as the result of their having offices in the United States and a clientele that was predominantly American. As these issues have been decided, many transportation agencies and companies have proactively engaged in changes that make their services more accessible to individuals with disabilities.

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See Also: Accessibility and Mobility; Driver Licensing; Elderly and Disabled Travelers; Handicapped Access; Social Equity and Discrimination in Transportation; Telecommuting and Telecommunications.

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Amtrak

See National Railroad Passenger Corporation/
Amtrak

Automated Guideway Transit

An automated guideway transit (AGT) system, also known as a people mover, is a fully automated transportation system in which driverless vehicles are conveyed along a grade-separated track. Grade separation means that the guideway is at a different

height than other surface transportation so as not to disrupt traffic flow at points where the automated and nonautomated vehicle routes would otherwise intersect.

The term *people mover* originated in the 1960s and is most often used to describe AGT systems that serve relatively small physical areas, such as airports, downtown districts, or theme parks. Originally the term was used to describe two separate systems: Westinghouse Electric Corporation's Skybus, which was prototyped but never developed as an elevated alternative to streetcars in Pittsburgh, Pennsylvania, and the Goodyear Tire and Rubber Company-sponsored PeopleMover, which opened as a Disneyland attraction in 1967. The latter moniker gained popularity and today is used generically to refer to AGT systems as diverse as moving walkways like those found in many airports to magnetic levitation vehicles like Shanghai's airport-metropolitan interchange trains.

AGT systems provide a cost-effective transit solution for delivering high levels of passenger service quality, scheduling reliability, and travel safety. They are used widely at airports, recreational parks, and central business districts, and are increasingly being applied on a larger scale in municipal settings, such as the Metromover serving downtown Miami, Florida, and the SkyTrain linking downtown Vancouver, Canada, with the greater metropolitan area.

Evolution of AGT

AGT was originally conceived as a means of providing mass transit services to accommodate rider loads exceeding those that could be served by existing buses or trams. While buses and trams offered an easy public transit solution for cities and suburbs suffering from traffic congestion, they did not have sufficient capacity or speed—due to frequent stops along a route—to make them an attractive alternative to transport by one's personal vehicle. While offering greater capacity and speed, subway systems generally were too costly to install in smaller cities and outlying areas. AGT offered a solution to bridge the transit gaps.

In traditional subway systems, the bulk of the cost is due to a need for large vehicle size and correspondingly large tunnels, rails, stations, and common system infrastructure. Part of the reason why large vehicle size is needed is the importance



A small monorail track above a water feature at Disneyland in California in February 2010. Theme parks were early adopters of automated guideway transit systems in the 1970s.

of headway, which is the safety distance required between vehicles traveling with limited sightlines through tunnels. Large vehicles under such conditions require a significant headway distance. Automated transit offered an opportunity to reduce headway requirements greatly and thus the size of vehicles and the necessary supporting infrastructure. With AGT, everything from track supports to station size could be reduced.

Smaller vehicles were lighter as well, which opened the door to a variety of suspension methods, from traditional steel wheels to rubber tires, air cushioning, and magnetic levitation. Automated steering systems still had to contend with issues of turning and rights of way without a person at the helm. For smaller systems, the simplest solution was to use a rigid guideway, such as a single light rail embedded in the ground or wall with an attached wheel pressed against it to steer—or guide—the unmanned vehicle along its set path. Some modern systems have eliminated the rail altogether,

replacing it with a virtual one that is read by sensors on the vehicle without the need to have an actual rail or mechanical connection.

AGT systems became a major area of U.S. Department of Transportation research in the late 1960s. By the late 1970s, Boeing and a number of other U.S. aerospace companies had entered the AGT market, followed in the 1980s by Ford, General Motors, and other automakers. At that time, development in the area of AGT began to ignite around the world. However, the market for small AGT systems for mass transit did not. Larger automated guideway systems were easier to integrate into existing mass transit structures, so they found a place in many overworked or underserved subway systems as a way to help support growing capacity and provide services to outlying areas. These types of larger AGT systems have since become a common fixture as part of many municipal mass transit systems.

Smaller scale people movers nevertheless found their own market niche, primarily in airports. One of the first AGT systems to be integrated at an airport was a monorail-style people mover installed at Tampa International Airport in Florida in 1971. The system included one- and two-car pod-like vehicles, serviced by two tracks, that shuttled passengers between terminals.

The Airtrans system installed at the Dallas/Fort Worth International Airport (Texas) in 1975 expanded the concept to include movement of people, baggage, mail, supplies, etc., between terminals and to and from remote operations centers and parking areas. The Airtrans system transported some 5 million people within its first year. Similar systems soon began to be installed at other airports around the world, and today they are ubiquitous at larger airports across Europe, Asia, Africa, and North America.

The theme park industry was also quick to realize the potential cost, infrastructure, and service benefits of AGT systems. The Walt Disney World Monorail System opened in October of 1971 to service the park's Transportation and Ticket Center, Magic Kingdom amusements, and Magic Kingdom Resorts. Throughout the years, the system has been expanded to include Epcot and other attractions and upgraded to enhance comfort, capacity, and control. The Walt Disney World Monorail System emerged early as a prime

model for the effective implementation of AGT systems at entertainment parks and continues to be a leader in that regard for park enterprises all over the world.

Advantages of People Movers

AGT systems can be operated at very short headways—typically 60 seconds or less—even in peak hours and can travel at high speeds as permitted by the track design and the distance between stations. The same service frequency of AGT systems can be maintained during off-peak hours as well without incurring significant operating costs thanks to the driverless automated guidance feature. The reduction in passenger waiting time during off-peak hours helps ensure quality of transit service.

In terms of both cost and capacity, most larger AGT systems fall between light rail systems and rapid rail transit systems. Smaller AGT systems like those found in airports or theme parks have average capital costs and capacities below that of light rail systems. However, AGT systems tend to have superior service quality, reliability, and safety compared with standard light rail and rapid rail transit systems. In terms of service quality, the precise control of speed, acceleration, and deceleration that AGT people movers provide deliver a smooth and efficient experience for riders.

The reliability of AGT systems at both peak and nonpeak times also adds to their high marks for service level. Consistency is also important on an operational level, as any delay in transportation at an airport, for example, may cause considerable loss to the airlines and to the entire airport enterprise itself, both financially and in terms of goodwill.

Safety is a key concern during the design and operation of any transit system, and even more so in the case of automated systems where there is no operator on board to address emergency situations. With AGT systems, passenger safety is ensured by fail-safe vehicle control systems and the application of advanced technologies for certain systems, such as door operations.

While AGT systems offer a cost-effective means for safe and efficient transport in activity centers such as airports and recreational parks, they also can be used to improve transportation planning, utilization, and public perceptions related to urban

transit services. AGT systems are significantly smaller than rail transit, enabling them to negotiate sharper turns and steeper grades. The smaller and quieter stations needed to support AGT systems can be integrated directly into buildings rather than requiring them to be stand-alone systems. The ability to integrate the stations into existing infrastructure makes AGT services easier to implement for transportation agencies and more attractive to the traveling public, which in turn helps increase ridership and boost financial viability. By connecting periphery areas and services, such as parking, with various parts of the urban center, cities can create a more focused, higher density pedestrian core while reducing downtown vehicle volume and traffic congestion.

The smaller scale and integration opportunities of AGT systems and stations also open opportunities to link real estate and business development processes with mobility systems planning. Enhancements to transportation infrastructure and services tend to be attractive selling points for both residents and businesses, helping feed a cycle in which those offerings lure dollars to the area that can then be used to justify further transit enhancements in a mutually beneficial cycle.

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See Also: Airport Parking and Ground Transportation; Airport Planning; Airport Transit Connections; Automated Transit Systems; Benefit–Cost Analysis of Transportation; Integrated Transportation and Urban Land Use Planning Models; Maglev Systems; Monorails.

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Automated Landing Systems, Airplane

Automated airplane landing systems, or autolands for short, are systems for automating the landing process of an aircraft, reducing the role of the flight crew in that process to one of oversight. Autoland is a subtype of autopilot system, often used in conjunction with an instrument or microwave landing system, and was originally designed to land aircraft in conditions of limited visibility. Today autolands may be used in a variety of visibility and weather conditions, often in conjunction with automated brake systems (which include wheel-based autobrake systems as well as the automated deployment of thrust reversers and spoilers to slow the aircraft's forward motion).

Autoland systems were first implemented in commercial aircraft by British airlines because of the especially poor visibility conditions that prevailed in the industrial cities of the United Kingdom and parts of western Europe, where anticyclonic activity in early winter formed thick fog mixed with particulate pollution from coal-burning plants. The frequency of accidents when pilots attempted to land in these conditions led to the development of a "specialized autopilot" system, based on the recognition that landings are all fundamentally similar.

Early work on the problem led to the groundwork for the crew resource management systems used today, as one pilot would monitor visual cues while the other would fly the plane by instruments. Further work aimed to automate the instrument landing system (ILS, which, like other instrument systems, relies on instrumental readings rather than visual cues). British work on the systems continued for years after, beginning in the 1940s, mostly as part of the government's Blind Landing Experimental Unit (BLEU). The main problem was the unreliability of ILS at altitudes below 200 feet. While this was acceptable at many airports, the particular visibility problems faced at British airports and those in some of the more industrial European cities were especially pronounced at ground level.

Autoland systems were implemented in British Royal Air Force aircraft and experimental BLEU aircraft in the postwar years and were incrementally adopted in commercial aircraft around the

1960s. The first autoland systems used in commercial aircraft were limited in scope compared to the full autoland systems of the military and are sometimes called autoflare systems. They simplified the landing procedure by controlling the flare of the craft (reducing its forward energy) while the pilot controlled the roll and yaw manually. Even this was a significant improvement and greatly reduced the number of landing accidents. Autothrust was soon added. These early commercial versions of autoland were not universally usable, however. They were effective for fog, and for the "London fog" (primarily low-lying coal smog) they had been designed to deal with, but they could operate only in stable conditions without turbulence or strong crosswinds. This situation gradually improved as integration with instrument landing systems and roll and yaw controls was improved.

Modern autoland systems receive signals from a ground-based instrument landing system, which is regularly calibrated according to international standards in order to ensure accuracy. Typically, the aircraft's interaction with the ILS at the destination begins well before the landing procedure, as the autopilot maneuvers the plane into its approach based on the ILS data. Two key elements of the ILS, operating as independent subsystems, are the localizer (LOC), an array of directional antennae pairs that transmit narrow beams to either side of the runway's center, making its location clear; and the glide slope (GS), an antenna array that provides vertical guidance data.

After the autopilot maneuvers the aircraft into position to land, the autoland system adjusts the throttle to maintain a correct approach speed and maneuvers the aircraft through the landing procedure and final descent. This involves following the glide path (the path dictated by the glide slope) and lining up with the coordinates given by the localizer, while descending in altitude at the right speed. This procedure is overseen by the flight crew, who check the autoland's performance against any visual cues that are available. Even in poor visibility conditions, the approach lighting of the runway is often visible and gives information about the aircraft's proximity to its target. At airports without towers, pilot-controlled lighting is used, with the approach lights and edge lights turning on and adjusting their intensity in response to pilot commands issued over radio.

The actions after touchdown are as important as the final descent. Typically, modern autoland systems are integrated with other automated systems for braking. Wheel-based systems increase friction on the wheels to slow their movement, while thrust reversers apply force in the direction opposite to the aircraft's motion to counteract its inertia and decelerate the vehicle. Spoilers, which are deployed automatically, create a turbulent airflow over the wings of the aircraft in order to prevent the lift for which they are otherwise designed.

Autoland systems are not perfect, but when something goes wrong, it is usually because of a failure of equipment at the airport, not on the aircraft. Glide slopes and localizers that have not been properly calibrated or frequently inspected may report incorrect information that can result in a crash when combined with poor visibility in which the flight crew has no visual ground reference.

Regulations require that a pilot be authorized to operate an aircraft with autoland. Categories of pilot authorization align with the three ILS categories (I, II, III) and require a specific number of actual and simulated flight hours during instrument conditions. For instance, federal aviation regulations require that a person applying for Category III pilot authorization already hold a pilot certificate with an instrument rating, as well as the type, category, and class rating for the aircraft for which the authorization is sought. In addition, applicants must have at least 75 hours of instrument flight time (of which no more than 25 or 40 hours may be simulated, depending on whether or not training takes place at an appropriate training center), 250 hours of cross-country flight time as the pilot in command, and 50 hours of night flight time as pilot in command. The ILS categories are based on "decision high" (the minimum height above the touchdown zone at which the landing begins) as well as visibility minimum and runway visual range. Category III is further subdivided into IIIa, IIIb, and IIIc, although IIIc is not an active category since it refers to conditions of zero visibility.

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See Also: Aeronautical Decision Making; Aircraft Design; Airplane Navigation Systems; Airplane Pilot Training; Collision Avoidance Systems, Airplane.

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Automated Passenger Counters

Automated transit passenger counters, or APCs, are electronic systems that maintain a count of passengers on board a transit vehicle (such as a bus or train). The Federal Transit Administration (FTA) requires ridership information to be reported to the National Transit Database (NTD) and accepts data from APCs, which it also inspects to ensure correct calibration. Without APCs, transit agencies must use manual schedule checkers, which generate estimated ridership data by manually counting the number of passengers on randomly selected trips and multiplying that figure by the number of trips in a given length of time (typically a month). Though the systems used for manual counts are usually carefully designed in order to minimize the effect of anomalous trips with unusually high or low numbers of passengers, they are nevertheless obviously less accurate than the true ridership counts provided by APCs. Further, APC counts are not distorted by transit agency actions that inadvertently distort manual counts. For instance, if a transit agency cancels an 11:30 bus because it has consistently low ridership, then by definition this will have little effect on the agency's monthly ridership totals; but using the manual method, it will have a significant effect on the count.

Accurate ridership counts are important for a number of reasons. Reporting to the National Transit Database is required as part of a larger group of data transit agencies are required to report to the FTA, including their compliance with the Americans with Disabilities Act and with the Title VI requirement to distribute transit services equitably. The information reported to the National Transit

Database pertains mainly to ridership, financial information, and safety and security (notably reporting the number of accidents and crimes that occur). Reported ridership information includes unlinked passenger trips (UPTs), meaning each trip, defined as a passenger boarding, traveling, and then disembarking, regardless whether they then transfer to another route; total number of trips according to time of day; and total passenger miles, meaning how far passengers travel.

For their own purposes, transit agencies usually track more data than this, including the relative popularity of various routes, seasonal or other time-based factors that impact route popularity (such as the impact of Red Sox home games on Boston's Green Line subway route), the length and frequency of trip delays, the correlation of safety or security incidents to specific routes or times, the correlation between crimes committed on transit vehicles and the crowdedness of those vehicles, and the frequency with which buses or trains are full to capacity and are unable to let all passengers board, requiring some to wait for the next vehicle. But most of this information builds on the accurate ridership count that only APCs can provide.

The complete level of detail provided by APCs has not only made it easier for transit agencies to report their information to the NTD and improved the quality of federal information on transit use, it has also challenged many of the tenets of conventional wisdom that had guided the transportation industry in the past. For instance, it used to be held as true—and many still advocate this view—that increasing fares or reducing services will lead to declines in ridership. The available facts even appear to bear this out sometimes, when the sampling and manual count method is used for estimating ridership. In recent years, for instance, the cities of Sacramento, California; Los Angeles; and Chicago have all cut their services in response to the budget tightening following the 2008 financial crisis, as well as other factors. Opponents of the cuts predicted severe ridership decline.

Severe ridership decline was subsequently reported by Sacramento but not by Los Angeles or Chicago. Sacramento does not use APCs; Los Angeles and Chicago do. While it is not possible to know for certain that Sacramento's ridership figures are inaccurate, the general trend does seem to indicate that using a manual count exaggerates the negative impact of fare increases and service cancellations.

Analysis

The ridership data collected by APCs is analyzed by the transit agencies using specialized geographic information system software like ArcView, which was developed for the transportation industry by the ESRI Corporation. ArcView takes database and spreadsheet data and combines them with geographic and spatial information to create maps that not only go far beyond the old-style schematic maps, by combining route and stop information with real-world geographic data and scale, but also incorporate ridership information, such as the number of riders who take certain routes at certain times and the relative popularity of different stops. The average load (number of passengers) carried by a bus or train at any given segment of a trip can be displayed. If a given route that has been experiencing overcrowding is only overcrowded for a particular segment of its trip, for instance, and this is shown to be consistently true, that is a problem that can and should be solved differently than if overcrowding is experienced at all stages of the route. Before the use of APCs and GIS software, however, only driver anecdotal data would have revealed this, and given how harried and distracted drivers are during conditions of overcrowding, the accuracy of that data is inconsistent.

The use of APC data with GIS programs can also help in planning potential routes, examining the effects of route cancellations, and evaluating the impact of changes to transportation infrastructure, such as detours or delays caused by construction. The effects of other changes can be explored as well, such as the potential increase in ridership as new residential areas develop or changes in commuting patterns as a business district expands. Attempting to extrapolate information from data is an operation that inherently has a considerable margin of error, especially when there are multiple factors at play (for example, in considering the impact of a new residential area, the transit agency cannot know in advance how heavily residents might depend on public transportation rather than using their own cars, bicycles, or walking). That margin of error becomes unusably large if the available data are not reliable—another argument in favor of APCs.

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See Also: Americans with Disabilities Act of 1990; Automated Vehicle Location Systems; Federal Transit Administration; Transit Performance Monitoring and Evaluation; Transit Ridership; Transportation Statistics and Databases.

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Automated Road-Pricing and Toll-Collection Systems

Road pricing and toll roads are travel demand measures that involve payment for accessing a designated area or motorway respectively, so that the costs of traffic congestion, which generally reflect a fundamental, usually peak-hour, imbalance between the supply of and the demand for road space, can be spread in accordance with actual road use. Automated (or electronic) road pricing and toll collection systems constitute an increasingly popular alternative to the conventional cash-based and tollbooth-oriented charging operations that have been used to collect transport revenue from motorists all over the world for many years now.

Electronic toll collection (ETC) reflects today's digital era because it uses technology to maximize revenue generation. This means that the toll collection mechanisms become more systematic and logistically reliable, maximizing road pricing's potential as an efficient revenue generator. More importantly, however, ETC operations radically enhance the road user experience in terms of

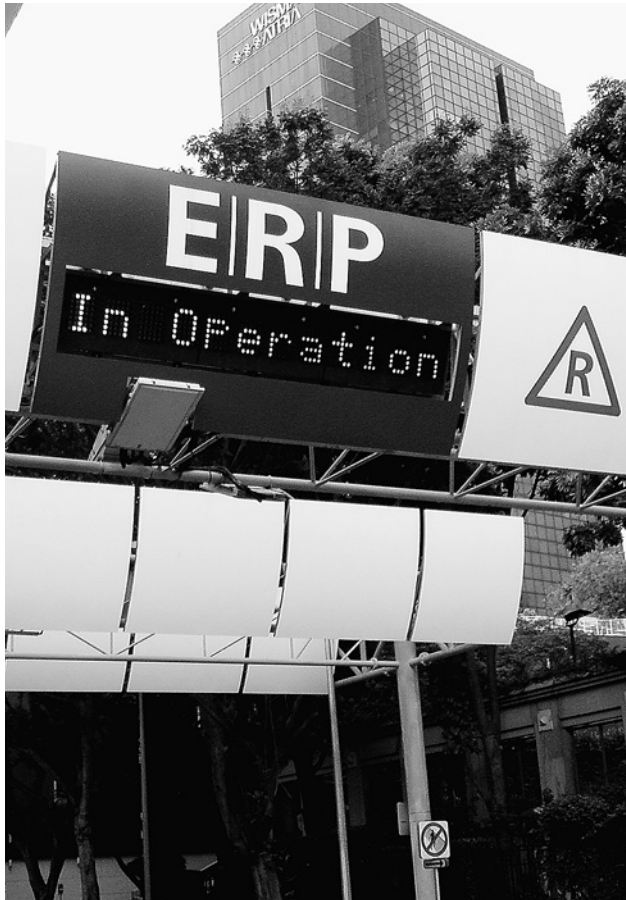
mobility, safety, reliability, and travel convenience, given that vehicles need not stop to pay the toll. This all-electronic, nonstop, open-road tolling process that replaces stationary payments prevents major highway bottlenecks occurring around toll plazas, which have been associated with other, less advanced methods of toll collection.

ETC systems in general and electronic road pricing (ERP) in particular provide proven congestion charging solutions that have been successfully tested in an applied sense around the globe. One of the reasons for this success, which differentiates these automated systems from less sophisticated ones, is that an intelligent tolling scheme allows the authorities running its operation to determine specific congested points within the designated road charging zone and, if they choose to do so, to fluctuate the rate of the charge according to occurring traffic conditions. Therefore, the charges can increase or decrease according to the specific requirements for road space demand at the exact time a driver is entering the pricing zone. This is a function that could ultimately provide the policy makers with a dynamic charging apparatus that offers, in principle, the potential to make tollway operations more flexible and equitable in real societal terms.

The Need for Automated Road Pricing and Toll Collection Systems

Road traffic congestion is costly not only to the individual but also to the society as a whole. More specifically, traffic congestion is responsible for travel delays and thus the loss of productive time, environmental degradation, excessive fuel misuse, and adverse health consequences for the people who have to live in cities subjected to it. A number of studies in the past referring to the particular characteristics of the traffic congestion occurring on toll roads concluded that the heaviest congestion takes place near toll gates, where cars traditionally had to stop in order to pay the charge manually. This means that a significant source of severe traffic congestion can be alleviated by introducing methods of tolling that permit vehicles to continue their course of travel without stopping on toll plazas.

"Intelligent tolling operations" refers to the payment of a fixed or varied charge for accessing a particular section of a road network that is usually



This electronic road pricing (ERP) gantry suspended over a road in Singapore is part of an open-road tolling system. Singapore's congestion-pricing ERP system was the first in the world.

highly congested, and they are organized around the automated identification of the vehicle entering the charging zone and successively (in most automated tolling scenarios, that is) the electronic collection of the fee.

This is being achieved through the wireless communication between an in-vehicle device and the system's toll gate antenna or an ERP gantry. This automated procedure allows the vehicle fleet accessing the charging zone to pass through toll gates without stopping, and thus without slowing down significantly the traffic flow. In some less advanced automated systems, cars have to reduce their speed on toll entries to allow the wireless operations to function properly, but even then this has a minor impact on the overall smoothness of the traffic flow when compared with the effect that the stop-and-pay tolling mechanisms have.

The Benefits of Automated Road Pricing and Toll Collection Systems

Reducing road congestion in areas where non-automated tolling systems could have led to traffic bottlenecks and crafting an unimpeded traffic flow are beneficial in multiple ways. Excessive fuel consumption resulting from vehicles that have to repeatedly stop and then reinitiate their trips at toll stations is eliminated. Emissions are consistently reduced, which aids in preventing global warming. This nonstop operating principle is also effective in diminishing noise levels around toll plazas. A more direct anthropocentric benefit is that drivers' cognitive efforts and stress levels are minimized as the charging process is automatic and drivers do not have to stop or carry money with them.

By charging road space, these advanced systems help regulate and distribute vehicle usage in a way that supports the road network's optimal use principally by encouraging motorists to consider alternative modes of travel. However, ETC systems in general could also direct road users to choose alternative travel routes to their destination to avoid the charge, travel during the off-peak periods, take different lanes in a motorway (e.g., not an express lane), or even adopt car sharing to split the costs of commuting. Electronic tolling has also been an efficient mechanism for keeping traffic speeds within the road system's optimal speed range because of its success in reducing traffic congestion.

Privacy Issues

A major social issue of automated tolling in terms of social implications is privacy. Privacy is regarded as a basic human right that is an intangible cornerstone for the society's well-being. ETC and ERP are both linked with the generation of a significant volume of detailed, aggregate, personal, and potentially dynamic identification data. These data are utilized as objective documentary proof of violations and allow electronically tagged vehicles to be accurately tolled even, in some cases, at a traveling speed of up to 100 kilometers per hour, but there is a less straightforward and potentially obscure dimension to this. The system's facilitators are given the opportunity to conduct real-time or retrospective surveillance of the movement of vehicles and people—something that could be a threat to the autonomy

of the individual and result in the loss of anonymity and possibly the loss of information privacy. Securing privacy in ETC applications therefore should be a fundamental design criterion, a clear statement of an individual's right to voluntary and informed participation in the scheme.

A Look Into the Future

The next generation of tolling systems is going to fully embrace the use of the Global Positioning System (GPS). A GPS-based tolling system could overcome the inflexibility of having physical toll entries by introducing virtual ones. By making automated distance-based tolling totally operational, road access charges will be calculated according to the actual distance covered by motorists within a charging zone and therefore could be entirely associated with usage criteria. This will make ETC systems even more equitable.

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See Also: Highway Planning; Road Pricing Schemes, U.S. and International; Toll Roads, Private.

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Automated Traffic Control Systems

Historically, traffic control for all modes of transportation took a number of forms, all of them relatively informal, to avoid collisions or to ensure that certain vessels or vehicles had the right of way. Even before the Industrial Revolution the growth of population and traffic in cities made traveling in the streets a dangerous proposition. As a result, in

London in 1868 an experiment was performed in which a lantern was used as a signal to let horse-drawn carriages know when to stop and when to go ahead. Initially, the traffic signal was successful. However, early the next year the gas line connected to the lantern ruptured, creating an explosion that killed the policeman operating the signal.

As busy as traffic had seemed with the proliferation of horse carts and carriages, the congestion and danger dramatically increased with the appearance of automobiles. Automobiles not only increased the number of vehicles in the street but, because of their speed and noise, increased the danger to drivers and pedestrians.

By 1912, the idea of using a traffic light to control who would go and who would wait at intersections seemed to be worth revisiting. In that year a traffic signal lamp was installed in Salt Lake City, Utah. Two years later a traffic light was installed in Cleveland, Ohio; the lantern was operated automatically but the controls could be overridden by police at the neighboring station.

The increased number of vehicles and drivers did nothing to increase caution on the part of those who actually drove the new machines. Accidents with horse-drawn vehicles or with other automobiles were all too frequent. The possibilities of a fatal crash with a train were not yet absorbed by drivers. As late as the mid-1920s, in an area as sophisticated as the region around New York City, accidents as the result of automobiles crossing railroad tracks when trains were running were fairly common. By this time, state and local governments as well as the federal government were concerned with rising fatalities and were beginning to take measures to establish traffic control systems that would move increasingly from those operated on the spot by individuals to those operated in an automated fashion.

Definition

Traffic control in one form or another has existed for every mode of transportation, be it horse-drawn wagons, canal boats, river traffic, railroads, or aircraft. While some parts of the traffic control processes have been automated, only in the area of controlling automobile and truck traffic has the process become completely automated. The chief means of exercising this control has been the use of traffic signals, now almost entirely the use of traffic lights

(which now number over 330,000, according to the U.S. Department of Transportation [USDOT]).

With the exception of those small towns that still have only one stop light in the center of town, municipalities have networks of traffic lights that form a traffic control system, and these systems are invariably networked and controlled in an automated fashion. It is these networks (and specifically not traffic signs) that constitute the automated system.

These automated systems are based on two types of traffic light systems. The first comprises lights that change their sequence (green, yellow, red) on a timed basis. The second is the variable light that operates based on information received from sensors. The length of time that the light stays on depends upon how heavy the traffic is. What has become a critical issue is the coordination between lights in the same system and how they operate given how heavy traffic is as well as other factors. In many instances, coordinating the signals among lights in one system has become an important activity in managing highway traffic in municipalities. Thus, automated traffic systems have accomplished a great deal in their primary mission of preventing accidents and saving lives. In other regards, however, it has become necessary to re-examine their use to counter other problems that they have created.

Improvements

While there can be no doubt that traffic lights have saved lives and will continue to do so, there is an adverse effect as well. The traffic control system networks in cities have been, in the past, largely uncoordinated or coordinated only partially. Coupled with the effects of increased numbers of vehicles on the road, the result has been the creation of congestion and traffic jams that leave drivers frustrated and cause delays. More importantly, the delays caused by uncoordinated traffic light networks are responsible for wasted energy and increased pollution from cars idling while their drivers wait for a light to turn green. According to the U.S. Department of Transportation (USDOT), 10 percent of all traffic delays are attributed directly to poorly coordinated traffic signals.

The National Transportation Operations Coalition (NTOC) is an organization composed of private-sector groups from all levels (national, regional, local) with an interest in safety and

effective transportation operations and planning. In 2005, the NTOC gave the nation's traffic control system a rating of D minus.

Despite the current problems, the means to improve this situation do exist, thanks to new technology as well as improved means of studying how traffic flows can be improved. As an example, in 2005, the city of Colorado Springs, Colorado, developed a plan for synchronizing its traffic signals. While there are variations in plans advanced by other cities as well as regions and states, the Colorado Springs document illustrates many of the factors that any government must address in order to improve its traffic flow by making improvements to its traffic control system. One thing to note in this and most other efforts is that the efforts do not include the construction and deployment of more traffic lights but instead improve the effectiveness of the existing system through a detailed study of current operations and the acquisition of advanced hardware and software.

In reviewing the state of the traffic control system in Colorado Springs, the board had to consider several factors in examining how cohort groups (referred to in the report as "platoons") of cars flowed and were affected by stop lights. First among these was to keep in mind the corridor speeds for specific stretches of the road network. If large numbers of cars exceed the speed limit or if they operate at a significantly lower speed than that posted, there will be excessive numbers of cars that must stop. The space between signals is also crucial because if there is a uniform distance (typically in Colorado Springs, at least, about half a mile) between signals, then coordinating lights to keep the flow moving will be easier to accomplish. If there are many lights spaced at variable distances, it will be difficult to effect the coordination of lights.

The road's capacity is another factor. If a road does not have the capacity to handle current traffic loads (unfortunately, a not uncommon occurrence as vehicles are increasing at a greater rate than that at which infrastructure is enhanced), the traffic will tie up. There are some fixes that can be made, but unless the roads can be widened (an unlikely option), these areas with a smaller capacity will continue to cause problems. Variations in traffic at different times of day can inform decisions about the best way to program timing for lights that can also mitigate the problem of congestion at these specific points.

Other factors also must be taken into consideration in the planning process. These can include pedestrian and bicycle traffic and the frequency of left-hand turn lanes and their signals. These lanes and lights, while they make it possible for drivers to make left turns in safety, also tend to cut the amount of time that the green light stays on for through traffic. Two-way traffic requires coordination of lights in two directions, which also complicates the calculations to be made. There is also the timing of the yellow light as a warning to stop (typically five seconds) and then the amount of time in which all lights are red (typically two seconds). While this last is also an important safety consideration, it too reduces the amount of time available for a green light for traffic to drive through. Finally, long-range planning must be conducted as a follow-up to the project. The recommendation is that the traffic control system must be evaluated again within two or three years after the first project. In cases where the route is heavily traveled, it should be reviewed and reimplemented more frequently.

Organizations

The expertise required to effectively coordinate the components of traffic control systems is not usually resident at the local or state level. There are organizations, however, both governmental and nongovernmental, that provide support to agencies seeking to improve their automated traffic control systems.

One of these organizations is the American Association of State Highway and Transportation Officials (AASHTO), which counts every state Department of Transportation (DOT) as a member and provides expertise derived from experience, design committees, and research. It develops standards and provides technical advice and best practices documents to state and local government organizations in transportation matters. It also has a national Committee on Uniform Traffic Control Devices that works on signs, devices, and design practices to be used at railroad-highway crossings. Another resource for state and local governments is the Institute of Transportation Engineers, a private organization that works with the USDOT. It is not only a repository of expertise but also performs outreach in the form of developing standards and publishes the *Traffic Control Devices Handbook*.

In addition to these organizations, there is also assistance from the Federal Highway Administration

(FHWA), one of the 10 administrative offices within the USDOT. The support it provides to improve the operation of automated traffic control systems is wide ranging.

A major area of FHWA assistance is the technical guidance and expertise it provides through the *Manual for Uniform Traffic Control Devices*, a publication that has been issued in one form or another since the late 1920s. The manual, generally referred to as MUTCD, provides guidance for all types of instruments to control traffic.

In addition to the MUTCD, the FHWA provides a wide range of support and expertise. This includes tools and software packages (it should be noted that there is also a healthy private industry that supplies traffic control planning software tools). The most significant of these is the Intelligent Transportation Systems (ITS), which includes communications capabilities data collection and analysis software. It also includes the Adaptive Control System (ACS), which, in its regular and "lite" versions, has been used successfully at several locations. Both the state of Texas and state of Delaware have used ITS successfully. Cities that have used ITS include Syracuse, New York; Seattle, Washington; Salt Lake City, Utah; Denver, Colorado; and St. Augustine, Florida.

All of these cities have had significant problems, but perhaps the city with one of the most notorious traffic problems that was solved using the latest technology in an iterative fashion is Los Angeles, California. In April 2013, the *New York Times* reported that the city had completed its Automated Traffic Surveillance and Control System, which was begun in 1984. The complete traffic control system comprises 4,500 street signals and is the largest and most complex of its kind. Using sensors at many locations, the system (using software specifically developed for this project) receives information that not only coordinates the main flow of traffic from point to point but also takes into consideration schedules for buses and when they get an extra green light.

Unfortunately, it is generally agreed that the improvement in the amount of traffic that passes through with less difficulty will result in even more traffic and probably within the near future.

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See Also: Automobile Accident Avoidance Systems; Automobile Accidents and Prevention; Congestion Mitigation and Air Quality Program; Highway/Road Capacity; Information Technologies and Transportation; Intelligent Transportation Systems; Smart Highways; Traffic Congestion; Traffic Flow.

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Automated Traffic Enforcement

Traffic laws regarding speeding and traffic lights are among the most commonly broken. This may be because individuals do not feel it to be morally wrong to speed or run traffic lights. No matter the reason, these laws are often broken, and law enforcement is tasked to do something about it. For this reason, automated traffic enforcement technology is often used to detect both speed limit and traffic light violations. By using these technologies, law enforcement personnel are able to refocus their efforts on other matters. However, these systems are not without their detractors, who raise concerns regarding privacy and civil liberties issues.

Speeding

Police officers may determine the speed of a vehicle through either radar or laser-based systems. Police have been using radar to catch those who violate the speed limit since the 1950s. This method determines the speed of a vehicle via echo location at multiple points over the vehicle's course of travel.

The technology is fairly limited, and many departments have transitioned to laser-based systems.

More technologically advanced police forces use a laser-based system commonly known as LiDAR, which stands for "light detection and ranging." The system is entirely laser based and shares no technology with radar, despite the similarity of the name. A typical LiDAR system determines the speed of a vehicle by firing several hundred beams of infrared light at its target. The beams are then reflected back to the LiDAR gun and timed, thus giving a reading. LiDAR systems may be manned or completely automated. Manned systems typically are operated by officers stationed on the side of the highway. Automated systems are programmed to detect speeding cars and record the times when violators are detected.

Traffic Lights

The basic elements of an automated traffic light monitoring system are as follows: one or more camera, one or more trigger, and a computer. Cameras may be either film based or digital, and the number of cameras may vary based on the standard of evidence required for a traffic ticket by local or state ordinance. Film cameras are more common to older systems, while digital cameras are newer and often capable of recording in a variety of ways.

Automated recording systems for traffic signals may be based on either induction loops or video loops. Induction-loop systems are based on electromagnetic circuits that are embedded in the asphalt beneath the street and connected to stationary cameras. The wire embedded in the asphalt is typically positioned near the stop line. From that position, the wire creates a magnetic field. If the field is disrupted by the metal mass of an automobile, the circuit is broken and cameras are triggered. The computer component is the hub of the automated recording system. The computer maintains and monitors the trigger circuit, monitors traffic signals, stores the images from the cameras, and timestamps those images with the date, time, location of the intersection, speed of the vehicle, and other information useful to law enforcement.

Video-loop systems operate in a manner similar to induction-loop systems, except they operate without the electromagnetic wire; instead, they rely more on digital cameras to determine when a red light has been run. The cameras are programmed

to recognize vehicles moving through the intersection when the light is red. Once recognized, video frames are recorded for the span of the infraction and time stamped. While these more advanced systems possess a variety of advantages over older induction-loop systems, the greatest advantage is that the asphalt does not need to be torn up every time the trigger needs adjustment.

Another major advantage of automated traffic enforcement systems is they defuse emotions surrounding the interaction between law enforcement and citizens. When drivers are pulled over, emotions often run high and dangerous conditions can develop; by eliminating the pull-over situation, citizens and officers are kept out of harm's way. If caught by the automated system, the driver can expect a ticket and a picture of the violation to arrive in the mail within one or two months. Laws vary by state on standards of evidence in this situation. Some states automatically issue the ticket to the car's owner; in these states, the camera simply takes a picture of the license plate. Other states ticket the driver. In these states, an additional camera is in place to capture a picture of the driver. The ticket is still sent to the owner of the car, but if the individual in the image is not the owner, the owner may appeal the ticket.

Controversy and Legislation

While a technology that simply catches and punishes individuals who are breaking the law may not seem controversial, there are some serious privacy concerns associated with automated traffic enforcement devices, especially video-loop technology. Not only do the video cameras capture those who are running red lights, but they also can be used to collect evidence of any crime or activity within the range of the camera. In fact, this is one of many reasons why the American Civil Liberties Union (ACLU) and other organizations oppose this technology.

This process through which cameras are used for investigations for which they were not originally intended is often referred to as "mission creep." The ACLU also argues that the time delay of as long as two months is a violation of citizens' constitutional rights to due process. These delays, it is argued, can inhibit the ability of the accused to appeal the ticket because it may be difficult to remember an event that occurred so long ago. The ACLU further



A red-light camera in use in Chicago, Illinois, in 2010. Automated traffic systems have raised privacy questions and have been banned by voters in numerous U.S. municipalities.

points out that automated systems tend to identify license plates incorrectly, and studies have shown that automated systems may increase incidents of rear-end collisions.

The ACLU is not the only group that has raised issues regarding automated traffic systems. These unpopular systems have been banned by numerous voter referendums and city council motions across the United States. Arguments frequently raised include that the cameras are installed solely for revenue purposes, the cameras are not an effective deterrent, and conflicts of interest are created when private contractors receive commissions based on the number of tickets generated by the system.

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See Also: Automobile Accident Avoidance Systems; Automobile Accidents and Prevention; Traffic Laws and Enforcement; Traffic Signals.

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Automated Transit Systems

Automated transit systems (ATS) are coordinated transportation systems in which vehicles are operated without a driver. An essential component of driverless systems is a fully protected route of travel. Specifically, the track along which the driverless vehicles move—whether it be at ground level, elevated, or underground—must be kept free of any obstructions, including potential access or crossing by pedestrians, automobiles, other operated vehicles, and even animals. The vehicle is controlled by an automated system, and there is no operator onboard to be able to visualize or observe a potential collision hazard ahead.

ATS vehicles themselves vary greatly based on size, shape, and underlying technology. For example, the ATS vehicles can be propelled by linear or rotary traction electric motors placed on the vehicle itself, by motors or even magnets embedded in the

track system, or by cable pulley. They can ride on steel or urethane wheels, rubber tires, air cushions, or have no ground contact at all, as in the case of magnetic levitation. Depending on their size, speed, and quantity of conjoined cars, the ATS vehicles can carry from several hundred to several thousand passengers in each direction every hour. Capital investment and costs associated with ongoing operations and maintenance vary significantly based on the system's size, location, complexity, level of technology, and carriage requirements.

The concept of automated transit systems began in the 1960s and has evolved over four decades to include more than 100 in-use systems at airports and urban centers in countries around the world. ATS offers advantages in the areas of mass transit service, travel speeds and capacity, and operational costs.

ATS Applications

The most prevalent application of automated transit systems is found in driverless rapid transit (DRT), followed by automated people mover (APM) systems and personal rapid transit (PRT) systems.

Driverless rapid transit systems involve group, rather than personal, rapid transit. The vehicles tend to resemble trains and are designed to carry a large number of riders along a predetermined route. The vehicles stop at multiple stations dispersed throughout the route. DRT is best suited for high-capacity, line-haul applications. The vehicles associated with DRT range from 50 feet to 100 feet (15–23 meters) and can be up to 10 feet (3 meters) wide. Their size makes them too large to maneuver swiftly through intricate systems associated with the people mover applications, especially when the vehicles are typically linked into one "train" by connecting as many as 10 cars together. The vehicles are usually self-propelled by attached motors and ride on steel wheels. The massive driverless vehicles can travel up to 60 miles per hour (100 kilometers per hour) and transport 10,000 to 50,000 passengers in each direction every hour.

Automated people mover systems are similar to DRT systems in that they involve group versus personal rapid transit. Like DRT systems, APM systems carry large numbers of passengers along a pre-selected route and stop at each station as it travels. However, unlike DRT systems, transit via APM systems is best suited for feeder and circulator applications, which are those involving more detailed

routes and passenger exchanges. The vehicles in an APM system are under 45 feet (14 meters) long and less than 9 feet (2.7 meters) wide, making them too small for line-haul service. The vehicles are generally self-propelled with rubber or steel wheels, but some are propelled by complex cable systems or utilize magnetic levitation rather than rails. APM cars can also travel up to 60 miles per hour and carry up to 10,000 passengers per hour per direction.

Personal rapid transit systems are much smaller in scale. They are intended to transport individuals or groups of up to six people traveling together via very small vehicles. The small, lightweight vehicles utilize short, direct routes along a dedicated aerial or underground cross-section guideway system and provide no intermediate stops. The PRT vehicles are 20 feet (6.1 meters) long at most and under 8 feet (2.4 meters) wide and often use battery power for propulsion. The maximum travel speed for most PRT vehicles is 20 miles per hour (32 kilometers per hour), and peak-hour capacity tops out at 4,000 passengers per direction each hour.

Advantages of ATS

Regardless of the specific type of ATS utilized, there are many intrinsic advantages to automated transit. For example, ATS vehicles offer higher average speeds than manned transit systems. Part of the reason is that when a driverless vehicle operates on a fully protected guideway or track, it can travel without impediments and thus progress at faster average speeds. The swifter travel time means that ATS vehicles also provide higher capacity capabilities because they can carry more passengers in peak hours than a similarly sized or configured system that travels at a lower average speed.

ATS presents potential cost benefits as well. While initial capital costs may be higher to acquire an automated control system with signaling, life cycle operating costs of an automated system should be much lower than manned systems because driver costs are not required. Moreover, the driverless feature provides added flexibility to the transit operations. For example, when ATS vehicles need to be added or removed from service to accommodate ridership fluctuations, it simply involves having a centralized control operator command the necessary vehicles, whereas the same situation in manually driven systems would require advanced driver and fleet scheduling and additional pay obligations to workers.

Service and safety are other important benefits of ATS. Automation enables efficiencies that provide passengers with more frequent service and shorter wait times, while advanced technologies facilitate passenger comfort and safety during transit.

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See Also: Airport Operations and Marketing; Airport Parking and Ground Transportation; Airport Transit Connections; Automated Guideway Transit; Benefit–Cost Analysis of Transportation; Maglev Systems.

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Automated Vehicle Guidance Systems

Automated automobile guidance systems, also referred to as automated vehicle guidance (AVG) systems, are components that take over the tasks of the driver of a vehicle, such as maintaining speed, driving the vehicle, and keeping a safe distance away from other cars and objects. In addition to convenience, this technology is considered promising to improve road network traffic conditions and enhance safety. AVG systems are commonplace in warehouses and business facilities that rely on moving robots for product assembly. These systems have not been fully implemented in cars, although technology for driverless cars is under development. The

purported benefits of AVG systems are improvement of road traffic performance, safety, and comfort because the role of the driver is eliminated.

Driverless Cars

One type of technology used in automated guided vehicles (AGV) is called free ranging on grid (FROG). FROG vehicles are equipped with a computer that contains a map of the area in which the vehicle operates, such as a GPS system. The vehicle starts from a known location and uses the map to determine the route to its destination. Wheel revolutions are used to determine how far the vehicle has traveled. Off the roads and in the industrialized setting, these vehicles can be loaded with cargo and sent on their own to unloading areas without the requirement of human operation.

FROG can even be used in public transportation hubs to transport travelers from one location to

another. These systems operate similarly to elevators and, with the push of a button, travelers can be transported. As with vehicles that load cargo, a computer with a map and calibration models determine how far the system has traveled and when it must stop.

FROG technology can only be used in a limited area. Automated highways are being evaluated as a way of extending driverless technology to larger areas. Such roads designated for automated travel do not currently exist, although developers imagine they could work alongside smart cars, which use features such as adaptive cruise control to maintain speed and improve safety conditions. The highways would gather data on speed, road conditions, obstacles, and directions and report these findings to the cars as they travel. The systems would be able to interpret and react to the information as it is received.

Traffic Management

When multiple AVG systems are in use, such as at a loading facility, the vehicles must be equipped with traffic management systems to prevent them from running into each other. Zone control is the most popular and widely used type of traffic management because it is simple to install and easy to expand. Zone controls survey the area surrounding the vehicle and use a wireless transmitter to send a signal to a fixed area. Each vehicle on the floor is equipped with this technology. When the zone is clear of other vehicles, they can come and go with ease, but they stop when another vehicle is detected. Once the AGV in the zone has moved beyond the zone, the “clear” signal is sent to one of the waiting AGVs.

When a vehicle occupies a zone, the AGVs behind it cannot access that zone but rather the next completely unoccupied zone behind the lead vehicle. The leading vehicle must proceed into the next zone before the trailing vehicle can move ahead into its next zone. The system works in this procession to avoid collisions on the floor. If a vehicle can occupy a zone, however, it is allowed to move freely within that area making all necessary stops before moving on to the next unoccupied zone.

Similar to collision avoidance systems in automobiles, AGVs use collision avoidance sensors to avoid crashes. Such sensors include sonic radar, optical, which uses an infrared sensor, and bumper, which is a physical contact sensor.



An automated guided vehicle (AGV) transporting goods in an industrial setting. AGVs are used for limited applications in public transportation; more sophisticated vehicles, such as driverless cars, are in development.

In general, forward-sensing control is useful when the zone in question is a straight path rather than a curved trajectory. When an AGV senses a vehicle in front of it, it remains in place until the lead vehicle moves out of the range of the sensing devices. There may be long runs in which forward-sensing control can be used, reducing the expense of the traffic management system significantly. In the remaining areas of the path where there are divergence path and convergence path areas, a form of zone control is used. The vehicles respond to both types of traffic control, depending upon the area in which they are operating.

General Motors and Carnegie Mellon University researchers are working together to develop driverless cars and hope to bring one to the market by 2018. Advocates of driverless car technology point to improved safety by removing driver-related risk factors, which would also improve traffic conditions and reduce pollution. Many remain wary about the idea of automated vehicles hitting roadways, however. Aside from the fact that people enjoy driving cars, eliminating human judgment in the event technology fails can be dangerous.

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See Also: Automated Traffic Enforcement; Automobile Accident Avoidance Systems; Automobile Accidents and Prevention; Automobile Safety Systems; Electronic Route Guidance Systems; Smart Cars.

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Automated Vehicle Location Systems

Automated vehicle location (AVL) systems are systems built into a vehicle to track and report its location, for example, for the purpose of tracking and managing delivery vehicles and tracking the progress of their freight. They are similar to, but often differentiated from, event-activated tracking systems, which similarly track vehicle location but for the purpose of recovery after events such as theft or an accident. The technology is functionally similar and sometimes the same—many vehicles include both functionalities, whereas vehicles marketed to consumers use AVL-type technology associated with a theft prevention service that monitors location only in the event of an incident. AVL systems are used principally for fleet, delivery, and driver management.

Early AVL systems used triangulation to derive the vehicle's location, based on radio signals. Radio signals from the vehicle to two points with known locations could be used to determine the location of the vehicle's transmitter. Triangulation is an old (and sound) method of location detection and is still in use today by the enhanced 911 system of cellular phones in order to allow 911 dispatchers to determine the location from which an emergency call is made from a cellular phone, which is not tied to a fixed location the way a landline is. The known locations used in triangulation may include signpost transmitters, which is common on transportation routes like railways and highways.

In such cases, the vehicle receives a signal from the signpost transmitter as it passes and sends back an acknowledgment, which confirms the vehicle has passed that checkpoint. This system is often used by delivery companies in order to check a vehicle's progress against a schedule. The use of specific checkpoints makes the comparison of progress easier. This system continues to be used either on its own or in conjunction with Global Positioning System (GPS) tracking, since it works on legs of the journey where GPS signals are blocked, such as by surrounding mountains or other terrain features.

Today, use of GPS has become widespread and is used in most modern AVL systems. Unlike radio signals, GPS signals are not distorted or drowned

out by electrical noise. Like cellular phones, they benefit from using an infrastructure already in place, that of the satellite-based navigation system originally launched by the Department of Defense, and thus do not require infrastructure investments by the company developing or using the AVL system.

They are more precise than either the signpost transmitter system or the radio signal triangulation system and can track a vehicle's location in real time. The system as installed in the vehicle receives GPS signals from the satellite system confirming the vehicle's exact location, which is then relayed to the dispatching or monitoring system, either continuously or in response to an inquiry.

Maritime AVL systems today are nearly always GPS based. Previously, the Long Range Navigation (LORAN) system was used for maritime and aviation navigation, using low-frequency radio signals and fixed radio beacons. The most updated version of LORAN, LORAN-C, was discontinued by the U.S. and Canadian Coast Guards in 2010 in favor of GPS. Private-sector maritime AVL systems based on LORAN had largely been discontinued years earlier, and the brief automobile AVL system using LORAN, which only worked on the country's coasts where the coastal radio beacons were close enough, had been discontinued in the 1980s.

AVL systems have a wide variety of commercial and public-sector applications. They are commonly used to track public transport, and in some cities apps have been developed that allow the user to follow the actual location of a given bus or train in real time, minimizing uncertainty about departure and arrival times. They are commonly used to manage any large fleet of vehicles, land or maritime, including delivery fleets, public and school transportation, and emergency vehicles like ambulances and fire engines. AVL systems are useful for any service that manages a fleet of vehicles that are dispatched to particular locations rather than following specific routes, such as ambulances, police vehicles, or taxis, because the dispatcher can instantly see which vehicle is closest to the site where response is needed and has to inquire only as to availability. Sales forces sometimes use AVL systems to dispatch sales representatives to different customer appointments.

Typically, these systems overlay GPS location data on top of a detailed map or other display that

is updated in real time. Weather, traffic, or other information may also be included, depending on the needs and concerns of the service. A computer-assisted dispatch system may automate the dispatching process by locating the nearest idle vehicle or may make suggestions to the human operator.

Asset tracking systems can also be incorporated into AVL systems, as is common with trucking companies using detachable trailers. The trailer and truck are monitored with separate AVL systems, which facilitates better inventory management of the freight being transported by trailer and reduces the amount of freight that is lost in transit after being transferred from one cab to another.

Advanced AVL systems may be integrated with other systems that update the central dispatch system with information about the vehicle's performance and current state, including fuel levels and mileage, tire pressure, engine condition, ridership, or freight information as applicable, and whether the vehicle is currently en route to a destination or available to be dispatched. Driver hours can also be logged for personnel and wage purposes, and driver performance information can be tracked, such as total miles traveled, speed, dwell time, unscheduled stops, missed stops, or traffic stops. This information may be either directly monitored or derived from monitored information.

In some cases this data may be requested by law enforcement agencies in order to determine which drivers of various vehicle fleets may have been near a given location at a given time for purposes of finding crime-scene witnesses.

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See Also: Automated Vehicle Guidance Systems; Automated Vehicle Monitoring Systems; GPS; GPS, Automobile; Intelligent Transportation Systems.

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Automated Vehicle Monitoring Systems

Many of the current technologies used to monitor vehicle position and operational status, such as automated vehicle location (AVL) systems and automated vehicle monitoring (AVM) systems, fall under the more encompassing term *intelligent transportation systems* (ITS). These typically consist of an electronic device installed in a vehicle, or a fleet of vehicles, with software that tracks the location and collects additional data that can be sent to an operational base. All technologies incorporated in ITS have a similar evolution beginning in the early 1960s. The creation of the global positioning system (GPS) in 1973 by the U.S. Department of Defense was an offshoot of the Defense Navigation Satellite System (DNSS), which originally used 24 satellites.

Anyone (individual, commercial, or military) with a GPS receiver can access the transmissions that satellites continually emit indicating time and position. With a minimum of four satellites and navigation equations, the GPS receiver calculates distances and times from relative position changes. GPS vehicle monitoring systems involve the installation of an electronic device in a vehicle to enable the owner or a third party to track the vehicle's location (and also receive additional information about the vehicle). These automatic vehicle monitoring (AVM) systems also combine a communications component such as cellular or radio transmitters to communicate the vehicle's location to a remote user. Vehicle information can then be viewed using appropriate software.

Common Uses

AVM systems have a variety of personal and commercial uses; with the increase in fuel prices, the technology is advancing rapidly. Transportation sectors in which the technology has already been established include commercial cargo carriers, municipal passenger travel (buses), fuel transportation (tankers), construction industry fleets, agricultural vehicles, railroads, courier/shipping trucks, and rental vehicles. For personal vehicle use, an owner may use AVM technology to monitor a driver's speed, location, travel history, distance traveled, fuel use, accidents, and hard-braking events. This tracking of driver behavior and performance can be applied by an employer for employees or by parents

of teen drivers. It can also track the vehicle in the event of theft.

AVM systems are indispensable as tools for fleets of vehicles. One of the more common commercial uses is for fuel-use monitoring. AVM prevents fuel theft, misuse, or drain. The system also can prevent unauthorized vehicle use; it may assist in supervision of vehicle operation time and workers' hours. These tasks are enhanced with fuel tank sensors, driver recognition and license plate ID technology, container management, alerts if vehicle/driver is leaving a customized geographic perimeter, tracking of acceleration/deceleration events, trip time, trip type, seat belt use, and various predetermined engine readings.

Components of AVM technologies include vehicle-to-infrastructure (V2I) communications and vehicle-to-vehicle (V2V) communications systems. By exchanging anonymous, vehicle-based data regarding position, speed, and location, V2V communication enables a vehicle to sense threats and hazards with a 360 degree awareness of the position of other vehicles, calculate risk, issue driver advisories or warnings, or take preemptive actions to avoid and mitigate crashes.

Vehicle-to-infrastructure communication is the wireless exchange of critical safety and operational data between vehicles and highway infrastructure. Though intended primarily to avoid or mitigate motor vehicle accidents, it also enables a wide range of other safety measures. By incorporating data exchanged between vehicles and infrastructure elements to perform calculations that recognize high-risk situations in advance, drivers may be alerted and warned in advance. An example of this technology is the ability for traffic signal systems to communicate the signal phase and timing (SPAT) information to the vehicle in support of delivering active safety advisories to drivers.

Economic Impact and Future Technologies

Productivity, efficiency, security, and safety are of key importance in both commercial and public transportation. Transit agencies are using ITS for improved schedule adherence, more accessible passenger information, and more data for dispatch management and planning. The integration of intelligent features and autonomous functionalities in vehicles will lead to major economic benefits, including reduced fuel consumption, efficient use of the road network, and reduced personnel. Crash

avoidance technologies can reduce a large number of vehicle accidents. Vehicle control systems that automatically accelerate and brake with the flow of traffic can conserve fuel more efficiently than the average driver. Reductions in fuel consumption yield corresponding reductions in greenhouse gas emissions. All commercial transportation sectors prevent financial loss and benefit enormously by monitoring use of fuel.

AVM and other intelligent transportation systems and their applications are evolving rapidly. Currently, new technologies for AVM and intelligent transportation systems are being developed that may offer even greater efficiency, safety, and economic benefits. Camera-based Computer Vision, radar, Light Detection and Ranging (LiDAR), and ultrasonic sensors have been employed to support applications that require simple object detection, such as advanced driver assistance systems (ADAS), vehicle collision avoidance technology, and advanced traffic management systems. Other applications for ITS include vehicle-to-vehicle communications, autonomous vehicle support, truck platooning, and intersection collision avoidance. Ultimately, these technologies will support the next generation of autonomous vehicles, such as the Google self-driving car.

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See Also: Automated Transit Systems; Automobile Accident Avoidance Systems; Automobile Safety Systems; Benefit–Cost Analysis of Transportation; GPS, Automobile; High Speed Highways; Intelligent Transportation Systems; Traffic Signals; Trucking, Computer Monitoring Systems and.

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Automatic Terminal Information Systems

The Automatic terminal information system (ATIS) is a means used by many towered airports around the world to distribute essential weather and airport-related information to arriving and departing aircraft. Most ATISs utilize automated voice technology to allow busy air traffic controllers to quickly type a new ATIS message rather than manually record a voice message. Most airports in a single country utilize the same recorded voice and message format for ATIS content to ensure consistency in delivery and communication. Similarly, the order of information provided in an ATIS recording is always the same, although the specific content may vary considerably. The recordings are updated at regular intervals, typically shortly before every hour, and when there is an important modification to the existing recorded information, such as a change in runway or approach or a pilot safety notice.

Message Format

Every ATIS message includes the same key components, which are presented below in the same descending order.

The first item in any ATIS message is the airport or facility name followed by a letter designation that serves to identify the specific version of the message. Letters are assigned in order, progressing through the alphabet from A to Z with each update. The letter is used to confirm that the pilot is referencing the latest information during correspondence with air traffic control.

The time of recording is given next and is presented as Greenwich Mean Time, regardless of the airport or pilot's location. Recordings are typically made 10 minutes to 15 minutes before each hour. There is a slight delay before the recording is available via ATIS so there may be a very small window of less than two minutes when no ATIS information is heard.

The third item on each recording addresses winds. Winds can be listed descriptively using words like "calm" in conjunction with details about direction or they may be given as a combination of direction and speed. Wind direction indicates the magnetic direction from which the winds originate. The information makes it convenient for pilots to compare wind direction with the runway in use to determine headwind. Wind direction may also be listed descriptively as "variable" or as being variable between two directions. Wind speed is provided in knots and may be presented as a specific number alone or as a number gusting to another number.

Visibility is the fourth item covered in ATIS recordings. It is most commonly given in terms of statute miles (1,609 meters = 1 statute mile) versus nautical miles (1,852 meters). Many locations report any visibility greater than 10 statute miles simply as "10sm." Anything that negatively affects visibility, such as mist, haze, or smoke, is also reported. Since visibility has the potential to vary greatly depending on direction of viewing and sun interference, any significant variances in visibility would likely be noted as well. Wind direction and velocity must be reported from certified direct-reading instruments.

The next topic covered on the ATIS message is clouds. Because clouds occur in multiple layers, the message is reported from the lowest layer to the highest, using feet above ground level. The type of cloud base is also reported, such as "broken" or "scattered." If the cloud coverage is less than one-eighth of the visible sky, the cloud section of the ATIS message may simply indicate "clear." The cloud ceiling—above which aircraft may be unable to climb—is indicated by the lowest cloud level assessed as being either broken or overcast. Many ATIS systems use automated sensors to determine cloud status. Any indications of lightning, dense clouds signaling storm activity, and unstable convection clouds must be reported via ATIS.



The control tower at Ronald Reagan Washington National Airport in Arlington, Virginia. Air traffic controllers enter critical automatic terminal information system (ATIS) data for pilots into standardized messages that are usually updated hourly.

Temperature and dew point are reported in degrees Celsius. The smaller the spread between the two, the more humid the air will be, resulting in a greater likelihood of haze, mist, or low-level clouds. The altimeter setting is listed next and is measured by inches of mercury in ATIS reports; it is used to help pilots confirm appropriate elevations. Temperature and dew point should be reported from certified direct-reading sensors when available, while altimeter information always must be reported from certified direct-reading instruments.

Critical pieces of information provided by the ATIS reports address airport approach and runways in use. This section of the ATIS message indicates runway assignments and specific approach instructions for the pilot during takeoff or landing.

The final component of the ATIS message is the remarks section, where nearly any topic of interest to the pilot may be included. For example, the remarks portion of the message could issue a

reminder to pilots to read back call signs and runway assignments, contact ground control when ready for takeoff, or even to be aware of birds in the area. This section of the ATIS message may also contain information such as taxiway closures, runway surface conditions, holding delays, or temporary air zone restrictions.

Benefits for Stakeholders

Automatic terminal information systems can provide significant advantages for almost every participant throughout the air travel process. For the pilot and air crew, ATIS messages provide rapid, reliable delivery of important flight data that not only improves preparation and safety due to inclusion of more detailed data but, with today's digital ATIS systems, also relieves air crew of previously required transcription duties for routine control messages. Instead, the ATIS information can be downloaded at any time during the flight when it is most convenient for the pilot and saved as a record for future reference and repeat listening if needed.

The enhanced efficiency in the cockpit often translates into improvements in airline operations. For example, better preparation and communication can result in fewer scheduling delays. For passengers, the smoother operations and reduced air crew workload means they can generally expect more on-time air travel and increased quality of flight service.

In the control towers, the benefits of ATIS come from being able to deliver convenient and comprehensive messaging to flight crews with minimal effort while greatly reducing the congestion of messages being transmitted on the regular tower and ground control radio frequencies. By reducing the routine workload of air traffic controllers, ATIS enables them to devote more time to the specific needs of actively engaged arriving and departing aircraft.

For airline operations centers, ATIS offers a streamlined process for dispatching and archiving flight operations messages that can be used to prioritize activities and plan ahead for potential delays, weather diversions, and other situations.

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See Also: Aeronautical Decision Making; Air Traffic Control; Air Traffic Flow Management; Federal

Aviation Administration; Information Technologies and Transportation; ICT, Social Impacts of.

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Automobile Access Programs

Automobile access programs include a variety of regulatory strategies that limit or prohibit automobile travel. Some programs allow automobile traffic but limit it to certain hours of the day or to certain days. Still other programs restrict automobile traffic to commercial vehicles and the vehicles of residents. The most restrictive programs prohibit automobile traffic from a specific area, creating pedestrian-oriented zones within urban areas. These programs typically are part of a larger program, such as a downtown revitalization program or a local traffic management plan, and are authorized by city government.

Although opposition to these programs may be fierce, the benefits of a well-designed program are many and significant. Effectively administered automobile access programs can reduce traffic congestion, improve safety, and decrease harmful vehicle emissions.

Limited Access Programs

One method of limiting access is the institution of no-drive days. Generally, no-drive days are voluntary and are designed to improve air quality. No-drive days have been in use since the 1970s, particularly in cities in western states. Denver and Phoenix have implemented no-drive day campaigns during

the three to four winter months when air quality is at its worst. The no-drive day campaigns have been credited with reducing emissions by approximately 2 percent in these two cities.

Driving restrictions based on vehicle license plate numbers have been implemented with limited success in cities such as Beijing and Mexico City, but such programs are rare in the United States. Studies have found that such programs rarely result in significant reductions in traffic congestion or emissions. Two-car families merely exchange vehicles, and shoppers merely defer trips. Furthermore, a substantial number of vehicles such as emergency vehicles, taxis, delivery vans and trucks, construction vehicles, and vehicles used by professionals such as medical personnel are granted exemptions.

Pedestrian Malls/Streets

Automobile-restricted zones can sometimes refer to a complete closure of streets to vehicular traffic. Pedestrian malls can be grouped in three categories: those that eliminate all motor vehicle traffic (restricting deliveries to off-peak hours), those that allow some motor vehicle traffic at very low speeds, and those that close the street during certain times. Typical examples of the latter group include farmers markets and festival closings. Temporary pedestrian zones can be created inexpensively by blocking an existing street with signs or barriers. Creating permanent public space is more costly, ranging from \$100,000 to several million. These zones prove most successful in places with a high volume of pedestrian traffic prior to the imposition of automobile restrictions.

The earliest pedestrian malls were created in the late 1960s and early 1970s to combat downtowns' loss of income to suburban malls. For the most part it was a losing battle for the cities. While New York City was garnering headlines for transforming parts of 34th Street into a pedestrian mall, other cities were reversing the process. But pedestrian traffic in New York equals that of most European cities, and high pedestrian volumes are consistent throughout the city. Kalamazoo, Michigan, turned Burdick Street into a pedestrian mall in 1959, inspiring 200 other cities to follow its example. Kalamazoo reintroduced cars to its downtown in 2000, and again other cities, such as Raleigh, North Carolina, followed its example.



This portion of Manhattan's Park Avenue Viaduct made up part of the seven miles of streets reserved for bicycle riders and pedestrians during the city's "Summer Streets" program in 2012. That year, 250,000 people participated in the program.

Four decades after first closing a section of downtown's K Street to automobile traffic, civic leaders in Sacramento, California, reopened a couple of blocks of the city's pedestrian mall as an experiment. Businesses instantly saw more retail traffic. The city decided to spend \$2.7 million to reopen the area to cars in hope of repeating the success of the experiment.

The Example of New York

In 2007, the Michael Bloomberg administration launched PlaNYC to make the city more appealing to pedestrians and bicyclists. A study had revealed that crowding was generally detrimental to commerce and safety and a deterrent to pedestrians, particularly those in wheelchairs, parents with strollers, people with disabilities, children, and the elderly who all usually need more space for walking.

In response, the New York City Department of Transportation (NYCDOT) created Broadway Boulevard from 42nd to 35th Streets in the summer of 2008, providing a corridor of public gathering spaces along with a protected bicycle lane. Over 150,000 people participated in a program christened Summer Streets in August 2008 when NYCDOT opened a seven-mile car-free route from the Brooklyn Bridge to Central Park to bicyclists and pedestrians for three Saturdays in a row. New York's Central Park and Prospect Park are closed to vehicular traffic for most off-peak hours and on the weekend. In 2012, Prospect Park reduced the space for cars to a single lane and created two separate, dedicated lanes, one for pedestrians and one for bicycles. In 2013, Central Park doubled the width of the pedestrian lane to 14 feet and added an 11-foot-wide bicycle lane that organizes cyclists by speed.

Street closures have been implemented in other large urban parks as well. Golden Gate Park in San Francisco began closing John F. Kennedy Drive on Sundays in 1967 and has since expanded the closure to also include some Saturdays. Piedmont Park in Atlanta provided parking to visitors to the Botanical Garden in a garage built into a hillside, eliminated surface parking, and added entrances for walkers and cyclists. Research supports the view of parks providing sustainability benefits to cities through parks' green oases where residents can escape from the noise and pollution of cities.

The Ciclovía Model

Urban parks are not the only oases. Gaining in popularity in the United States is the *ciclovía*, a concept pioneered in Bogotá, Colombia, in the 1980s. A *ciclovía*, which literally means "bike path," closes a street route to automobiles and transforms city streets into a safe zone for residents to run, bike, skateboard, dance, and enjoy a wide variety of other recreational and social activities. The first *ciclovía* in the United States was held in the summer of 2007 in El Paso, Texas. As of 2011, more than 46 cities in the United States and Canada sponsored *ciclovía*. Some are sponsored by city governments, but many are organized by community groups. Among the largest are CicLAvia in Los Angeles, Sunday Streets in San Francisco, Open Streets Chicago, Open Streets Minneapolis, Atlanta Streets Alive, and Cyclovía Tucson. Baltimore's *ciclovía* project is almost as old as El Paso's, and the movement continues to grow.

Jackson, Mississippi, and Indianapolis are among the cities that hosted their first *ciclovía* in 2013.

Ciclovía, like other road closures, sometimes inspire protests from motorists and residents of neighboring communities, who fear traffic in other areas will become more congested, complain that cars will be diverted onto residential streets, and argue that merchants will lose money and museums and other attractions will lose patrons. But a broad consensus supports the events as a means of fostering healthy cultural interactions, economic development, and physical activity—characteristics of a thriving community.

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See Also: Automobile Culture; Bikeways/Bike Lanes, Road Design Issues of; Greenways; Pedestrian Malls and Skywalks; Pedestrian-Friendly Design;

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Automobile Accident Avoidance Systems

Not that long ago, automakers were content with merely minimizing the impacts of accidents or investigating their causes, also termed amelioration and analysis. Avoidance differs from amelioration. Accident avoidance systems are proliferating in automobiles around the world, from backup cameras that allow the driver to see objects and people behind the vehicle to facial recognition software that notices a driver dozing and sends an alert signal to wake the driver. Adaptive cruise

control uses radar and lasers to adjust speed and preserve a safe distance between vehicles. Featured in advertising, avoidance systems sell well because any driver with any experience at all has at one time or another experienced a near miss or driven distracted.

An old technology from the 1970s is the event data recorder, the black box, debuted by Chevrolet on the 1974 Caprice Classic, which was among the first cars with airbags. The Caprice black box recorded airbag deployment and provided repairers and manufacturers with information about the results of the crash and its magnitude.

Active crash avoidance tools include the antilock brake systems (ABS) that keep tires from locking and skidding under hard braking. ABS also offers traction control, adjusting power to each individual brake as needed. Stability control is also a feature, and it uses a different set of sensors to track lateral movement, steering angle, and so on, and it can automatically apply brakes to keep the vehicle on the proper path.

Newer technologies are well beyond those that detect slippage. Collision mitigation and avoidance systems use sensors (radar, cameras, ultrasonic sensors, lasers) to track activity outside and around the car. The systems may decide the vehicle is approaching another too fast, in which case they will sound a warning, flash a light, vibrate the seat or steering wheel, or any combination of the above. Some Ford systems will prime the hydraulic lines in anticipation of a hard stop. The Toyota precollision system will prime the brakes and also tighten the seat belt. Mercedes, Volvo, and Infiniti systems brake for the driver. Debuted in 2012, Volvo in Europe and Asia has an airbag between the hood and windshield that deploys to cushion a pedestrian struck by the vehicle.

Blind Spot Monitors

Blind spot monitoring systems generally offer a warning light on the exterior mirror or pillar and may beep as well. The 2013 Ford Fusion offers cross-traffic detection, a combination of the rear-view camera and blind spot monitor. Nissan and BMW offer multiple cameras around the vehicle to give a bird's-eye view of the car's environment. Another avoidance tool is proximity detection that beeps as a vehicle gets nearer and nearer to an object.

Anti-Drowsiness Lane Departure

Lane departure systems offer warnings and either an alert or an automatic return to lane. Cadillac ATS and XTS not only beep and flash but also vibrate the seat. Mercedes and Infiniti brake to bring the vehicle back to the proper lane. In the future, power steering systems will automatically correct for lane departure. The trigger for lane departure systems is a nonsignaled lane change, and turn signal activation neutralizes the warnings.

Mercedes offers Attention Assist as an option. The system monitors various elements and notifies the driver when it is time for a break. Infotainment systems with voice capability reduce driver distraction.

Electronic Stability Control

According to the National Highway Transportation Safety Administration (NHTSA), electronic stability control (ESC) reduces accidents of all types by 15 percent. It measures speed and tilting of the vehicle around a curve and, when the vehicle deviates from the curve, slows the vehicle, brakes, and stiffens outboard shocks to return the vehicle to the appropriate path. Volvo and Mercedes lead the industry in automated technology. Mercedes has included vehicle stability systems as standard equipment on all models since 1999, and Volvo has one of the best electronic stability control (ESC) systems.

Adaptive Headlights

Adaptive headlights improve dark-road visibility. Some vehicles have automatic high-beam activation if it is dark enough. These headlights also sense an oncoming vehicle and turn themselves to low beam to avoid blinding oncoming drivers.

Adaptive headlights move with the driver's steering and provide improved visibility around curves. Adaptive headlight-equipped vehicles decreased claims 10 percent.

BMW and others offer infrared lighting for better night vision. With pedestrian detection, these systems can differentiate between humans and animals and notify the driver if something is crossing the road.

Autonomous Braking

Another technology is the autonomous braking system. Volvo, Mercedes-Benz, European Ford, and General Motors provide this technology. GM's

version, called Driver Assist, senses problems in the front or back of the vehicle and helps stop the vehicle; it is called Driver Assist, available in the 2013 Cadillac XTS, and it combines radar, cameras, and ultrasonic sensors controlled by a computer. Driver Assist also warns a driver that another car has entered the lane ahead and decreases the speed of the car if the cruise control is on. Driver Assist includes blind zone alerts and lane departure warnings.

Lexus is first in the world with an advanced pre-collision system (APCS), which uses cameras and radar and detects pedestrians in the vehicle's path and brakes the vehicle to avoid an accident.

Because left-turn accidents are the leading cause of death for motorcyclists, BMW has a pilot system called Left Turn Assist. In-car GPS detects that the vehicle is in the left-turn lane and scans ahead for motorcycles and cars, emitting a warning sound and displaying warning signals on the instrument cluster if one is detected. If the driver fails to stop, Left Turn Assist brakes the car to avoid a collision.

Volvo's Queue Assist stops the car and gets it back to speed in stop-and-go traffic. Volvo XC60s with City Safety Collision Avoidance System have 27 percent fewer fender benders, according to the Highway Loss Data Institute (HLDI), a subsidiary of the Insurance Institute for Highway Safety (IIHS). The Volvo system incorporates forward-looking laser sensors to locate and measure the speed of vehicles ahead. A loud beeping and a flashing dashboard light warn the driver to brake immediately to avoid a collision. Below 20 mph, the system automatically brakes the car. It can prevent collisions between two vehicles traveling at less than 10 mph difference. For speed differences greater than 10 mph, it cannot avoid the collision but it can reduce the impact. The result, claimed by Volvo and verified by the IIHS, is fewer accidents and fewer injuries. Lower insurance costs are a result too. The technology has potential in the future to work in high-speed as well as low-speed events, and that development would not only cut costs but save lives.

Vulnerabilities

Technology is not infallible, as indicated by the recall in 2014 of almost 44,000 2012–13 Honda Fit hatchbacks because the stability control software was not adjusting for oversized tires on the sport model, thus allowing skidding on turns. The Volvo City Safety system in the 2011–12 S60 had

a tendency to brake the car at low speed without apparent cause. There was no option to disconnect the system.

Accident avoidance systems, like any other part of the vehicle, are not foolproof. They fail due to dirty sensors, fogged cameras, malfunctioning radar—the general problems of advanced technology. When it has to be replaced, the cost is quite high. For one thing, the repair technician has to have specialized training and tools for working on an accident avoidance system. Also, accident avoidance systems do not make for a driverless vehicle. The driver still has to be alert and in control of the vehicle.

Benefits

A 2012 HLDI study found that forward collision avoidance systems and adaptive headlights reduce accidents significantly. Forward collision avoidance warns when a crash with a car ahead is about to happen. The same study found no accident improvement for lane departure warnings, which alarm when a vehicle drifts away from its lane.

The HLDI study found that autonomous braking and adaptive headlights were significant improvements. Lane departure warnings caused more accidents, not fewer. And there was no noticeable benefit to blind spot detection and park assist. The major improvement in claims was in damage to other vehicles more than to the accident avoidance-equipped ones. The study did not examine frequency of collision claims, but it revealed a slight reduction. Injury claims also decreased somewhat.

The Mercedes and Volvo systems without autonomous braking lowered crash rates but not as much as versions with both forward collision warning and autonomous braking. Presumably, drivers do not react as efficiently as machines and are less able to avoid accidents.

Claims for vehicles with adaptive headlights fell by up to 10 percent on Acura, Mazda, Mercedes, and Volvo models. All but one brand had a marked decline in injury claims. All four systems benefited most types of insurance coverage, and they worked in more situations than researchers expected, but there was no clear explanation why.

Buick and Mercedes lane departure warning systems increased collision and property damage claims, but the increases were statistically insignificant. It was also possible that the data were insufficient because drifting off the road is uncommon.

The technology also may be ineffective when lane markings are not clearly visible. For insurance purposes, the technology was of the future, not of today's claims. The institute did not study lane departure systems that do not allow a vehicle to leave its lane, but there was some anticipation that such systems would have a greater impact than simple warning systems just as autonomous braking enhanced the effectiveness of forward collision warning systems. The less the vehicle relied on the driver and the more it relied on itself, the safer it seemed to be.

The HLDI study examined forward collision avoidance systems on Volvo, Mercedes-Benz, and Acura, and found that Mercedes and Acura automatic braking systems reduced insurance claims 14 percent, and Volvo automatic braking reduced claims by 10 percent. Vehicles with only warning but no automatic braking had only a slight reduction in claims.

Vehicles with lane departure warning systems in some cases had higher claims, possibly because the cameras were not working properly or because the warnings were so frequent that drivers ignored them or turned the system off.

Accident avoidance technology is most often optional and limited to luxury brands. In 2012 avoidance systems formerly reserved for luxury brands began appearing in more mainstream vehicles. The 2012 Ford Taurus offered forward collision avoidance as an option.

Vehicle-to-Vehicle Communications

The NHTSA is emphasizing vehicle-to-vehicle (V2V) communications that will allow vehicles to talk to each other, collecting information from other vehicles and the road. Information may pertain to accidents ahead, pedestrians in the road, or red light-running vehicles. The vehicle's onboard electronics can assimilate the information and establish a safe speed or advise of emergency maneuvers. The NHTSA reports that 80 percent of crashes are due to driver error. Volvo is committed to V2V, having a goal of zero crash deaths in Volvos by 2020. And the future of V2V naturally is the fully autonomous vehicle, driverless cars either in "road trains" or individually. Taking out the driver eliminates road rage, rubbernecking, and other driver errors.

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See Also: Automobile Accidents and Prevention; Automobile Design; Automobile Driver Warning Systems; Automobile Safety Systems; Collision Avoidance Systems, Automobile; National Highway Transportation Safety Administration; Traffic Detection Systems.

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Automobile Accidents and Prevention

The 2007 population of the United States was roughly 300 million people. The 200 million licensed drivers had 255 million vehicles; 71 percent of American adults drive to and from work. Between 2000 and 2005 more than 6 million auto accidents occurred in the United States. Approximately 2.9 million people a year were injured during that period, and more than 42,000 a year were killed. Vehicle accidents kill approximately 115 people every day in the United States, and about 20 percent of the dead were passengers.

Motorcycle accidents in 2007 killed 5,000 people. Motor vehicles killed 4,600 pedestrians that year: 25 percent were in intersections, 9 percent involved large trucks. Even in lightly populated Nevada the annual death toll from accidents is over 400 people, 37 percent in cars and 32 percent in light trucks. Seventy-seven nonmotorists and bicyclists die in an average year.

The Insurance Institute for Highway Safety (IIHS), which uses the Department of Transportation Fatality Analysis Reporting System data, notes that 2011 saw 32,367 traffic fatalities. The American Automobile Association (AAA) estimates vehicle accidents cost \$162 billion a year, over \$1,000 a year per American. Causes include inexperience, speeding, intoxication by alcohol or drugs, and simple recklessness.

Driver Error

Driver error accounts for more than 80 percent of fatal and injury crashes in Ireland, probably close to the same in the United States. Driver errors include tailgating, failure to signal, and drifting from one's lane. Driver inattention/lapse accounts for a million crashes a year in the United States. In a Nevada study, 51 percent of vehicle accident deaths were in accidents where the vehicle left the roadway. Drivers err when they behave badly by tossing cigarette butts, honking, driving with bright lights or with no lights, trying to squeeze ahead in traffic. Speeding and not wearing seatbelts also qualify as errors contributing to traffic accidents.

Intoxication

Driving while intoxicated is a major driver error. Blood alcohol levels above 0.08 percent contributed to a third of the fatalities recorded in the Nevada study. Impaired driving kills on average nearly 30 Americans each day. That is one every 48 minutes. The 2010 total was 10,228 people, 31 percent of all traffic fatalities. The annual cost is over \$51 billion. In 2010, 1,210 children died in traffic accidents, 211 in alcohol-related incidents (17 percent of the total.) Of these, 211,131 were in the vehicle driven by the impaired driver. Intoxicated driving kills more young people, with one-third of the alcohol-related fatalities in 2010 involving persons between ages 21 and 24, 30 percent age 25 to 34, and 25 percent age 35 to 44. Twenty-eight percent of motorcyclists



The Insurance Institute for Highway Safety (IIHS) conducted tests on a 2010 Hyundai Tucson GLS using this crash test dummy at the IIHS Vehicle Research Center in April 2010. According to the IIHS, there were 32,367 traffic fatalities in 2011.

killed in 2010 had a blood alcohol content (BAC) of 0.08 or greater. Motorcyclists age 40 to 44 account for 44 percent of fatalities.

Drowsiness

The AAA Foundation for Traffic Safety finds that people who sleep six to seven hours a night double their risk of a drowsy/sleep-induced crash compared with those sleeping eight hours or more. Sleeping less than five hours elevates the risk four to five times. An Australian study indicates that being awake for 18 hours produces impairment equivalent to a BAC of 0.05, while 24 hours equals a BAC of 0.10. A BAC of 0.08 is legally drunk in most states.

The National Sleep Foundation (NSF) in 2005 reported that 168 million people, 60 percent of adult drivers, had driven drowsy in the past year, with 37 percent, or 103 million, saying that they actually fell asleep while driving. Thirteen percent of the dozers reported being asleep at the wheel once a month or more. The NSF *Sleep in America* poll of 2001 found that over a fourth (27 percent) of respondents indicated they had driven drowsy to or from work more than once a week, and 4 percent admitted they were drowsy drivers just about every day.

Eleven million drivers (4 percent) had an accident or near accident due to dozing or feeling greatly fatigued. According to the National Highway Traffic Safety Administration, driver fatigue accounts for 100,000 police-reported accidents involving roughly 1,550 deaths, 71,000 injuries, and \$12.5 billion in losses. The numbers might be low because there is no breathalyzer test for sleepiness, there is no police training or state standard for identifying drowsiness, self-reporting is not reliable, and other causes such as alcohol may overshadow drowsiness as a contributing factor. Countries that have more consistent reporting procedures than the United States indicate that drowsy driving is a cause of 10 to 30 percent of all crashes.

Among adults between 18 and 29, 71 percent are likely to drive drowsy compared to 52 percent aged 30 to 64 and 19 percent age 65 and over. Men are more likely than women (56 to 45 percent) to drive drowsy and 2 to 12 percent more likely to fall asleep while driving. More likely than average to doze and crash are commercial drivers, shift workers, drivers with children in the household, and those with undiagnosed disorders such as sleep apnea and insomnia.

Sleep deprivation and fatigue contribute to other accident-causing behaviors such as inattentiveness, stress (42 percent of drowsy drivers), impatience (32 percent), and speed (12 percent.) Only 22 percent of drivers pull off the road when drowsy.

Inexperience

Younger drivers are more likely to drive drowsy than older ones. Because of inexperience, teens are less likely to judge the risk of danger or recognize hazardous situations, more likely to speed and follow too closely, and less likely to wear seat belts. Younger drivers are also more likely to be involved in risky

and sometimes fatal behaviors. Vehicle accidents are the leading cause of death among teens. In 2010, every day, seven people aged 16 to 19 died in motor vehicle crashes. That was a total of almost 2,700 in 2010, and there were 282,000 emergency room visits by teens due to automobile accidents. Of male fatalities between ages 15 and 20 in 2010, 39 percent were the result of speeding, and 22 percent had been drinking. Only 54 percent of teens in 2011 claimed they wore seat belts when riding with someone else, and in 2010, 56 percent of fatalities after drinking and driving were not wearing seat belts.

Teens are three times more likely, based on miles driven, to be in a fatal crash than are drivers aged 20 and older. Vehicle accidents are the cause of 36 percent of all deaths of teens. The total cost of motor vehicle injuries for the 14 percent of the population aged 15 to 24 is \$19 billion for males, \$7 billion for females, 30 percent of the total cost for males, 28 percent for females. For drivers aged 15 to 17, the cost was \$34 billion in property losses, medical bills, and related costs in 2006. That year, 15- to 18-year-old drivers had 974,000 accidents that injured 406,427 and killed 2,541.

Prevention

Accident prevention checklists recommend that drivers practice defensive driving, stay away from drunk drivers, and don't drive drunk or tired, slow down, and get driver safety training. Well-established accident prevention methods include remediation therapy for offenders, random breath testing, and a high level of publicity.

Law enforcement is a key preventive. Speed limit enforcement reduces accidents, given that speed may contribute to upward of a third of all fatalities. Sobriety checkpoints reduce crashes about 9 percent by taking drunk drivers off the streets. Ignition interlocks installed in the vehicles of prior offenders that won't allow operation by anyone with an unsafe BAC (0.02–0.04 percent) can reduce arrest rates for impaired driving by 70 percent.

Preventive measures for teens include graduated driving licenses (GDL) that allow teens to learn to drive under more controlled conditions. The GDL reduces fatality and injury crashes by up to 38 and 40 percent, respectively, for 16-year-olds. The GDL requires parental involvement, which in itself can reduce foolish and fatal driving behavior. Other accident prevention measures include mandating

lower centers of gravity for high-profile vehicles, roll cages, safety glasses, and insurance rates based on performance.

Safety Testing

When prevention fails, minimizing consequences entails using safety equipment, such as air bags, crumple zones, energy-absorbing bumpers, seat belts and child restraints. Highway modification to incorporate roadside guardrails as crash barriers and crash cushions as well as other safety features will reduce accidents. Beyond these safety measures, safer vehicles become important. Safety research labs exist at various levels.

Crash tests are a critical tool for reducing loss of life and property from vehicle crashes. Crash tests destroy vehicles to verify that standards for vehicle safety are appropriate. There are several types, including frontal impact tests, side impact tests, rollover tests, offset tests, and roadside hardware crash tests.

A frontal impact test crashes the vehicle into a solid concrete wall at a set speed. Offset tests entail a collision of only part of the front of the car with a barrier or another vehicle. Offset tests involve the same crash impact as full frontal impact tests, but the impact affects a smaller area of the car, which has to absorb the full impact. Side impact tests are vital because side impact collisions produce high fatality rates due to the minimal crumple zone to absorb the collision, meaning that the occupants take the brunt. Rollover tests evaluate a vehicle's ability to maintain structural integrity, particularly from the roof supporting pillars. Roadside hardware crash tests evaluate crash cushions and crash barriers' ability to protect passengers. Other roadside hardware whose potential for damage requires test and minimization includes sign posts, light standards, and guard rails.

SAFE Laboratories of Santa Barbara, California, has for almost two decades been devoted to research and analysis of automobile safety and crash testing. Sled testing and full-scale vehicle crash tests incorporate front, rear, and side impacts at speeds of 35 miles per hour (mph) and greater. Areas tested are passenger safety systems, restraints, seating systems, padding, structural damage, and air bags. SAFE uses onboard instrumentation and high-speed cameras and other testing devices for real-world accident simulations.

The U.S. government's Insurance Institute for Highway Safety (IIHS) is a nonprofit scientific/educational agency. The Highway Loss Data Institute (HLDI) is also a government organization and it supports the IIHS. Both agencies have insurance carrier backing. The IIHS rates vehicle crash worthiness and provides an online searchable database by make and model or by type. It also provides a list of prior winners of awards for crashworthiness and safety of occupants in a crash. These awards rest on five tests; all five favorable outcomes earn a rating as "Top Safety Pick." The tests are (1) a moderate overlap front test to evaluate effectiveness of the crumple zone, (2) a small overlap front test for cases with minimal crumple zone impact, (3) a side test of protection when struck in the side by a pickup or SUV, (4) a rollover test, and (5) a rear test that tests restraint prevention of whiplash. The IIHS also tracks incorporation of crash avoidance systems such as collision warning and automatic braking, and it tests bumpers as well as insurance loss by model. The IIHS has been conducting research since 1969.

Another research organization, this one at the federal level, is the National Highway Traffic Safety Administration (NHTSA), a division of the U.S. Department of Transportation. The NHTSA replaced the National Safety Bureau in 1970 and is responsible for safety programs under federal laws of 1966 and after. Its mandate is to reduce economic losses as well as deaths and injuries from traffic accidents. It sets and enforces vehicle and vehicle equipment performance standards and provides grants to state and local governments for highway safety programs. It also deals with vehicle defects, fuel economy standards, promotion of child restraints and seat belt use and air bags, and reduction of drunk driving. Its research arm examines traffic safety and driver behavior to improve safety.

Crash test programs throughout the world are devoted to making vehicles safer for owners and drivers and to giving potential purchasers safety performance data, a significant consideration in purchasing both new and used vehicles.

The type of crash test is important. When the IIHS introduced the small overlap test in 2012 some previously high-performing vehicles fared poorly. Toyota was among those with a long tradition of five-star IIHS safety ratings but poor ratings for the new test, which evaluates the force of a collision

on areas that are relatively weak. But 13 or the 18 midsize family cars tested survived the side impact test satisfactorily and maintained the top rank in the older tests. The IIHS intentionally added the small overlap test to evaluate historically high-scoring vehicles, the ones that the manufacturers had designed and developed with the four older IIHS tests in mind.

The IIHS found in 2009 that, for vehicles with good front protection, small overlap crashes generated nearly a fourth of frontal crashes that produced serious or fatal injuries to front-seat passengers. The small overlap test recreates a collision between a front corner and another vehicle, a utility pole, or a tree. A fourth of the front end hits a 5-foot-tall rigid barrier at 40 mph. Many vehicles' crumple zones do not protect fully against this sort of accident, and the impact can push wheels and suspensions into the passenger compartment or spin the car and force the driver's head away from the air bag.

Driving is a dangerous affair, and manufacturers and safety testing organizations can do only so much to make vehicles accident resistant. The key element in accident prevention is the driver.

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See Also: Automated Vehicle Guidance Systems; Automobile Accident Avoidance Systems; Automobile Safety Systems; Collision Avoidance Systems, Automobile; Distracted Driving; Impaired Driving; Intelligent Vehicle Highway Systems.

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Automobile Culture

The American public's love affair with the automobile has influenced economic, residential, recreational, popular culture, and many other aspects of life in the United States and around the globe. Although automobiles first became popular at the turn of the 20th century, a series of developments that coalesced during the 1950s ensured that this trend became a phenomenon. A variety of factors, including the development of the interstate highway system, the sprawl of urban areas, increased mobility of the population, and growing leisure time, all led to the embrace of the automobile culture. As American trends increasingly influenced global preferences, the automobile culture became an international occurrence.

Background

Shortly after 1919, automobile pioneer Henry Ford predicted that any working individual who desired a car of his or her own would soon be able to purchase one. By 1950, over 25 million registered

automobiles were on the road. Although this number of automobiles represented an all-time high, many of these vehicles were built before World War II and were in poor repair. By the end of that decade, however, the number of registered automobiles had risen to nearly 70 million, with many of these late-model vehicles built after the conclusion of war-imposed rationing and other restrictions. By 1960, one in six Americans was employed directly or indirectly as a result of the automotive industry, and the inauguration of the interstate highway system in 1955 greatly increased the use of private vehicles for leisure travel.

This rapid embrace of automobile culture changed many aspects of American life. More cars and better engineered roadways made it possible for many to flee beyond municipal borders, and a new suburban lifestyle developed that increased the number of individuals who commuted a distance from their homes to work. Low-interest home loans available to servicemen returning from World War II made the suburban lifestyle a reality for many younger Americans, and this population shift in turn created the need for new shopping centers, supermarkets, gas stations, and other commercial entities and conveniences. This rapid growth of suburbia resulted in more than 33 percent of Americans' living in such areas by 1960. During the previous decade, 11 of the United States' 12 largest cities saw population declines, with only Los Angeles, in many ways the archetype for embracing automobile culture, seeing growth in the number of its residents.

Impact

As traditional cities lost population to their suburbs, these urban areas saw declines in tax revenues and the city centers deteriorated. As pressure for the desegregation and integration of public schools increased, "white flight" also grew, as many parents sought to ensure that their children stayed in schools with predominantly white student bodies. The rapid sprawl of suburbia made the expansion of public transportation systems economically prohibitive, which in turn sped up the growth of the automobile culture that had spurred the decline of many rapid transit systems.

As traditional city centers withered, new types of businesses that fully embraced the automobile culture were created. Before the 1970s, few Americans

ate outside the home with any regularity, except for meals prepared at home and carried to another location for consumption. Drive-in restaurants became popular during the 1950s—passengers reluctant to leave their cars could remain in their automobiles while carhops brought items ordered directly to the customer. Other restaurant chains, intending to cater to the mobile customer of the times, originated during the 1950s and 1960s, with industry icons such as McDonald's, Burger King, Kentucky Fried Chicken, and Wendy's all originating during this period.

These businesses used consistent menus nationwide, as well as easily recognizable logos and signs that could be spotted from the road, to cater to a clientele that was dependent on the automobile. Drive-in movie theaters also grew in popularity in response to the love affair with the automobile. With a large outdoor screen, ample outdoor parking, individual electronic speakers, a concession stand, and a projection booth, drive-in theaters catered to families and other moviegoers, although their popularity had declined by the 1980s.

Shopping malls developed in suburban areas to permit their newly affluent residents to avoid the inner-city experience entirely. Free-standing, and often enclosed and climate controlled, shopping malls supplanted traditional downtown shopping areas, further leading to urban decline. Often anchored by popular department stores, shopping malls were usually accessible only by automobile and featured abundant and no-cost parking as a way to entice shoppers. As shopping malls grew larger and more popular, they helped other retail areas go into rapid decline, which limited greatly the shopping options for those who did not have access to an automobile. As concerns regarding urban sprawl and the desire to engage in environmentally friendly practices grew, problems with the automobile culture came to be recognized.

Consequences

As more Americans began using automobiles, roads and highways were built to cater to them. This in turn enabled the growth of suburban areas, which also created the need for new businesses that catered to the newly affluent residents of these outlying areas. The allure of the suburban lifestyle, combined with white flight from the cities, meant that these areas grew at a rapid rate, and

new businesses sprang up to cater to them. These businesses, which included restaurants, shopping malls, drive-in theaters, and others, were designed to appeal to owners of automobiles and, intentionally or not, excluded those who did not have access to a car.

As concern for the environment grew during the 1970s, the negative influences of the rapid growth of the automobile culture began to be examined. Suburban sprawl, crowding, inefficiency, and the decline of central city districts all were associated with automobile culture, and increased calls came for better public transportation options and more urban planning. Despite this resistance to automobile culture, the siren song of the vehicle remained strong, causing many initiatives intended to curtail its use to fail. Many Americans remain dependent upon their automobile for access to retail shopping, entertainment options, and employment opportunities.

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See Also: Accessibility and Mobility; Automobile Access Programs; Automobile Industry, Economics of; Automobiles, Passenger; Commuting; Recreational Travel; Urban Sprawl Versus Compact Development.

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Automobile Design

In 1924, automotive sales in the United States had reached the saturation point, and to maintain unit sales, Alfred P. Sloan Jr., the head of General Motors, suggested annual model-year design changes to motivate car owners to buy replacement vehicles each year. The idea of a new model every

year originated with the bicycle industry. Critics called Sloan's strategy planned obsolescence, although Sloan preferred to call it dynamic obsolescence. This strategy had long-term effects on the automobile business, product design, and eventually the American economy.

Smaller companies could not match the pace and expense of yearly restyling, and Henry Ford did not like the annual model-year changes because he believed in the engineering principles of simplicity, economies of scale, and integrity of design. In 1931, General Motors outpaced Ford's sales and dominated the automobile industry until the 21st century.

Frequent style changes transformed the field of automotive design, creating the necessity of using a body on frame instead of the lighter but less flexible monocoque—or external skin support—the design most European automakers used. Many design innovations progressed into the 21st century, but automobile designers followed certain core ideas as they produced their yearly models, including safety, fuel efficiency, air pollution, computerization, automatic parking assist, and global positioning systems, as well as predicting and designing automotive innovations.

Automobile Design: Safety Seat Belts—Inflated and Otherwise

In 1965, Ralph Nader published a book called *Unsafe at Any Speed* that motivated automobile companies and designers to add and improve automobile and truck safety features, including seat belts, padded dashboards, collapsible steering columns, and improved bumpers.

In 1959, automobile maker Volvo introduced the three-point safety belt over the skepticism and resistance of the automobile industry and the general public. Initially, Volvo installed the three-point safety belts only in Sweden, but by 1963 all Volvos, including the ones destined for the United States market, included front-passenger three-point belts. Later, automotive engineers began designing seat belts with more comfortable straps and better force limiters. Seat belts of the future will feature computers and microprocessors controlling the way a seat belt works before, during, and after a crash.

Design engineers, including those at Ford, have worked for decades to improve seat-belt safety. An



Visitors viewing energy efficient design features in a car engine under development at Argonne National Laboratory in 2013. New government standards will require automakers to build vehicles that average about 35 miles per gallon by 2016.

engineering team at Ford Research and Advanced Engineering developed the first inflatable rear seat belt, which Ford introduced as a premier safety feature beginning with its 2011 Ford Explorer. According to Ford, its design team accepted the challenge of making an inflatable rear seat belt that combines the working of a conventional seat belt with some of the safety features of a front-seat air bag. Ford engineers created a tubular air bag that folds like an accordion so that it can be stored inside the seat belt. An instant after a crash, the inflatable bag breaks through the seat belt fabric as it fills with air and expands sideways across the body and shoulders of the person in the belt. The inflated belt helps distribute the energy generated by the crash across five times more of the passenger's body than a traditional belt. As well as

enhancing safety, the air bag also adds comfort by contributing cushioning to the seat belt.

Possibly with an eye on the National Highway Traffic Safety Administration (NHTSA) statistics saying that only 61 percent of rear seat passengers in the United States are using their seat belts, Ford projected that the additional safety and comfort would motivate rear-seat passengers to use rear seat belts in the Ford Explorer more often. Eventually Ford plans to offer the inflated seat belt in all of its cars worldwide, although it faces challenges in adapting the design for cars other than suburban utility vehicles (SUVs), and there are some safety concerns for passengers in booster seats.

Air Bags

Next to seat belts, automotive designers have made the most significant safety advances in air bag technology. The NHTSA calculates that the seat belt–air bag combination is the most effective safety combination available, reducing the risk of death by 61 percent. It estimates that since 1998 air bags have saved nearly 28,000 lives.

The NHTSA has required new vehicles to have advanced front air bag systems since September 1, 2006. Since 1990, 291 people have been killed by air bags, and so designers have configured the newer air bags to turn on and off based on the weight and position of vehicle passengers.

Although Mercedes-Benz has installed air bags in all its models since 1986, the U.S. government did not require air bags for the driver seat and front-seat passenger until 1998 for automobiles and 1999 for light trucks. Swedish car maker Volvo introduced side-impact air bags in the mid-1990s, and BMW has also pioneered advanced air bag technology. The BMW M3 featured as many as eight air bags, and its 7 Series offered knee air bags that protect the legs and help prevent the driver from sliding down and forward during a crash.

Designers have created air bags shielding the pelvis, chest, and head that could be deployed from the door, seat, or roof of the vehicle. In some vehicle models, side curtain air bags protect the head; some remain inflated for as long as 5 seconds during rollovers.

General Motors pioneered the dual-depth passenger-side air bag in which the manner of inflation depends on variables like seat position, crash

severity, size of passenger, and whether or not the seat belt was fastened. In newer Volvo models, dual-stage air bags work on a slightly different principle that adapts inflation speeds to specific conditions. The air bags fully and rapidly deploy in severe crashes, whereas a less severe crash triggers a slower 70 percent inflation.

Other safety features include head injury protection, antilock brake systems, all-wheel drive and traction control, and electronic stability control systems.

Automobile Design Trends

Twenty-first-century design trends feature short windows that make the roof appear lower and the entire car seem sleeker. Rounded roofs and fewer right angles create a sense of seamlessness where the glass and metal meet. However, the rounded designs pinch the windows tighter and make it more difficult for the driver to see where the front and back of the car end. According to Max Wolff, director of Cadillac exterior design at General Motors Corporation, consumers like all of the metal surrounding them because it makes them feel safer, even if that feeling is an illusion.

Aggressive design once confined to sports cars has become an important element. Both older and younger vehicle buyers prefer more aerodynamic designs, which boost fuel efficiency. In an aerodynamic design, the tail of the vehicle is higher than the front, creating a smooth wedge that cuts through the air. More dramatic wedge shapes further increase fuel efficiency, even though a higher trunk lid makes it harder for the driver to see out the back window.

Automobile Design and Fuel Efficiency

An automobile's fuel efficiency is the relationship between the distance traveled and the amount of fuel the vehicle uses while traveling. The energy in fuel is required to overcome wind resistance, tire drag, and other factors in propelling the vehicle and in providing power to vehicle systems such as ignition or air conditioning. Driver behavior can affect fuel economy; for example, sudden acceleration and heavy braking both waste energy. Vehicle fuel consumption is a major factor in air pollution, and importing fuel is a large part of America's balance of trade, so driver behavior affects the American economy and the environment.

America's first fuel efficiency standards were implemented in 1978 as a response to the 1973 to 1974 oil embargo, and they roughly doubled the fuel efficiency of new cars in the 10 years following the embargo. Over the next two decades, the standards stagnated and produced very little improvement in fuel efficiency. In the 21st century, the United States is getting back on the fuel-efficiency track by requiring automakers to build vehicles by 2016 that average approximately 35 miles per gallon and emit roughly 30 percent less pollution. When they are fully implemented, these new standards will save more oil and reduce more tailpipe pollution than any other existing government program.

The Obama administration is extending fuel efficiency and pollution standards for passenger vehicles and setting the first standards for commercial trucks. President Obama announced plans to move forward with new fuel efficiency and pollution standards, and the U.S. Department of Transportation (DOT) and Environmental Protection Agency (EPA) have been directed to establish joint fuel efficiency and pollution standards for new cars and trucks. They will establish new fuel economy and pollution standards for light-duty vehicles, a category including cars, SUVs, minivans, and most pickup trucks, through model year 2025. The agencies will also set the first-ever fuel efficiency and global warming standards for medium- and heavy-duty trucks including delivery vans, city buses, and long-haul tractor-trailers, through model year 2017.

Automobile Design: Computerization

Modern automotive designers and engineers have a powerful tool—computer-aided design, or CAD software—to help them imagine, design, and refine their ideas. Patrick J. Hanratty helped pioneer the use of CAD to automate repetitive drafting chores for General Motors in the mid-1960s. The use of CAD systems in automotive design expanded significantly over the years as computer costs decreased and technology expanded.

Today's automotive engineers and designers use CAD systems to quickly draw their designs, work with other experts, and simulate actual vehicle performance. Designers can even create visual prototypes for consumer research and marketing and, by streamlining the development process, auto

manufacturers can reduce the time from drawing board to assembly line by rolling out new models faster than ever before. CAD automotive systems can help identify and eliminate design faults. Computer simulations take 3D models through a variety of situations including high speeds, harsh weather, accident impacts, and everyday wear and tear. Designers have made cars safer by using CAD to design and test seat belts and air bags and to improve visibility, energy transfer and absorption, and vehicle control and handling, including anti-lock brakes.

The combination of computers and cars also took other forms. Volkswagen (VW), in conjunction with Stanford University, built an autonomous Audi TT that can drive at high speeds without a driver. Using real-time software lets Shelley, Stanford's robotic racecar, achieve reaction times of just a few milliseconds. Scientists at VW's Electronics Research Lab hope that technology from Shelley might eventually be used to help drivers control their cars during emergency maneuvers, preventing crashes.

Other automobile companies like Ford and Lexus are building auto-parking technology into their high-end sedans, and Toyota equips some of its models with the Toyota Monster Xbox All-Terrain Gamer. Mercedes brought out the Mbrace app, which, acting like a key fob, allows its owner to locate, lock, and unlock the car. Carsharing pioneer Zipcar takes the idea a step further by locating and reserving a Zipcar and then programming the horn to honk so the renter can find it more easily. Chrysler uses a 3G module to turn its cars into mobile WiFi cafes with e-mail capabilities.

Automatic Parking Assist

In 2003, Toyota Motor Corporation launched the intelligent parking assist system (IPAS) for Lexus models in the United States, designed for reverse parallel parking. Using an onboard computer and built-in front and rear cameras, the system estimates the size of the parking space and maneuvers the vehicle appropriately. Front and rear sensors detect the proximity of nearby vehicles. A dashboard display shows the image of the parking space. In one of the few human interventions, the driver determines the exact position of the vehicle in the lot by maneuvering arrows on the screen. The IPAS takes over steering control and parks the vehicle. By 2006, the system could recognize minute objects

and it featured parking sensors. Newer versions parallel and reverse park.

In January 2011, Ford introduced its Active Park Assist parallel-parking technology as an affordable option in the Ford Focus, Explorer, Escape, and Flex and in its Lincoln MKS and MKT. The technology uses an ultrasonic-based sensing system and electric power-assisted steering to position the vehicle, calculate the optimal steering angle, and quickly steer the vehicle into the parking spot.

Global Positioning Systems

Throughout the decades, automobile technology advanced and automakers shifted their focus from basic transportation to designing features like the global positioning systems (GPS) that made vehicles safer, more comfortable, and more easily operated.

A GPS consists of space, control, and user segments. The space segment consists of two dozen satellites funded and controlled by the U.S. Department of Defense that orbit the Earth twice every 24 hours at approximately 10,900 nautical miles above the Earth's surface. The control segment is a series of monitoring stations located at different sites on Earth that update and correct errors in the navigational messages of the satellites.

The user segment is a receiver that receives radio waves from the satellites in orbit to determine how far away it is from each satellite by keeping track of the time it takes for a radio wave to travel from the satellite to the receiver. Four satellites are used simultaneously to pinpoint the receiver's position on Earth. Information from the first three satellites narrows the range of possible locations to two points, one of them usually indicating a point not on the Earth. A fourth satellite is used to confirm the target location.

The accuracy range of a typical GPS receiver is about 50 feet, which may not be practical for locating a small object like an automobile. Differential GPS (DGPS) is a system that improves the accuracy of the GPS receiver to about 7 feet. Several reference GPS receivers are placed at stationary locations with known coordinates and these receivers compare their known locations to the location information they receive from the satellites. The receivers broadcast the range errors they detect from each other and from every satellite and a DGPS receiver can pick up range

error information and correlate it with the satellite signals it receives to discover its true position. The accuracy depends on how fast the reference receivers broadcast their signals.

Installed in a car, a GPS can provide useful information about the car's position and the best travel routes to a given destination by linking to a built-in digital map. A monitor in the car shows the relevant part of the map and the driver can enter the target location; the computer then calculates the best route and displays it instantly. A GPS can respond to user preferences and map a route that avoids highways or avoids local roads and, if it is detailed enough, can also provide the locations of the nearest gas station, supermarket, restaurant, hotel, and ATM machine. Some GPS units can issue voice directions to guide drivers as they travel.

GPS also tracks distances traveled on a particular trip, vehicle mileage, and speed. It keeps a record of driving activity, including the address of each destination, names of streets traveled, and how long the vehicle remained at each location to allow owners to monitor the use of their cars by other drivers. Some systems issue warnings when the car is speeding and when the car is approaching a speed trap, and other systems monitor the car condition and issue warnings when the battery is low or when it is time to change the oil.

When a car is stolen, GPS can aid in its recovery. If it is integrated with the automobile security system, GPS can notify the car owner by phone or e-mail when the car alarm is triggered and indicate the car's location. An owner can contact the GPS unit from outside the car using a cell phone or the Internet, and can start the car engine remotely and unlock the door, solving the problem of accidentally locking himself out or the locks freezing in bad weather.

In addition to its applications in private vehicles, commercial shipping companies use GPS to speed the delivery of cargo by allowing companies to track their fleets, record the movement of their trucks, and control route planning. Car rental companies can equip their cars with GPS technology to find stolen rental cars and charge customers for dangerous conduct like speeding.

The original analog Electro Gyrocompass system used an accelerometer to navigate using stationary navigation, as the GPS system was not yet generally

available, but Honda claims to have created the first navigation system starting in 1983 and leading to its general availability in the 1990 Acura Legend. As early as 1985, a U.S. company called ETAK introduced its own digital map navigation system with a geographically limited effective range. Research on Honda's digital map navigation system resumed in 1987 after a three-year delay.

By 2013, automobile manufacturers and improved technology offered many global positioning services and companies that were eager to manufacture them. Magellan, Tom Tom, and Garmin are some of the most popular global positioning systems sold in the United States and around the world.

The availability and accuracy of the global positioning systems provide increased safety for vehicles on highways, streets, and mass transit systems. GPS helps eliminate many problems with the routing and dispatch of commercial vehicles and facilitates managing mass transit systems, road maintenance crews, and emergency vehicles. GPS technology is advancing very quickly. New models are being developed every year to correct problems in older versions, focusing on improved accuracy, better reception, and even more user-friendly features.

Design Futures

Designing the cars of the future is a global activity, and master's degree students from the Royal College of Art's Vehicle Design Course in London have contributed their imaginations and innovation to the global design pool. Some of their ideas include a car that ages with its owner and, unlike its mortal owner can be reincarnated; an Audi that builds itself with robotic 3D printing technology; and a camper vehicle that is a cross between a motor home, a yacht, and a power boat. Other ideas include the Lexus Impulse 2033, an open-top three-seater in which the driver sits between his or her two passengers and a nocturnal car with glass auto tint panels, electroluminescent panels, and bright xenon lights.

Australian journalist Antony Funnell and other vehicle visionaries have speculated about vehicles that can brake, steer, and accelerate under optimal freeway conditions without human driver help. Eventually, a vehicle could be entirely robot and computer controlled and respond to a driver getting in and directing it to drive home.

Clicking from search engines to vehicle engines, the internet company Google has been working on a combination of hardware and software that could make the driverless car a reality in a decade or so. In 2012, Google announced that its driverless test vehicles had logged more than 311,000 miles without incident or accident. In an interview, *Time* magazine editor-at-large Harry McCracken emphasized that before Google's cars are consumer ready, ordinary cars will be able to efficiently park themselves inside a garage and come to drivers when summoned. He said that there are already cars on the road that can parallel park automatically.

Larry Burns is professor of engineering practice at the University of Michigan, former head of research and development for General Motors, and advisor to Google's driverless car project. He cites a technology called lane keeping that enables a car to keep itself in the correct lane and a feature called collision warning, that enables a car to avoid an obstacle in the road. Cars are equipped with speed range adaptive cruise control so drivers can keep a safe space between vehicles in front of them. Companies like General Motors are developing a feature called super cruise in its future models. Daimler is offering Distronic Plus, which resembles super cruise.

According to Burns, tailored and driverless vehicles will free drivers for more essential activities and force a restructuring of society in terms of energy, roadway safety, land use, and climate change. Fully automated cars will be a link in a larger system needed to support an eventual, complex and sophisticated society system of driverless cars; many of the components needed to construct and operate a system for driverless car technology already exist. Once the system is in place it will be capable, affordable, safer, and self sustaining.

Burns predicts that cars will be 75 percent lighter with 90 percent fewer parts. They will connect by a communications infrastructure web that will support many driving capabilities, conveniences, and features. He predicts that current energy problems, road safety issues, and urban congestion will dramatically subside and that drastically smaller cars will enable people to move more safely and efficiently.

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See Also: Air Pollution, Automobiles; Automobile Driver Warning Systems; Automobile Safety Systems; Automobiles, Passengers; GPS; GPS, Automobile; Trucking, Computer Monitoring Systems and.

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Automobile Driver Warning Systems

According to U.S. Department of Transportation statistics, 32,367 people died and 2,217,000 were injured in motor vehicle crashes in 2011. To reduce these numbers, the Department of Transportation created the Intelligent Vehicles Initiative (IVI) to help drivers avoid hazardous mistakes. As part of the IVI, automobile manufacturers have expanded their focus beyond improving the crash-worthiness of their vehicles to include developing and installing automobile driver warning systems in them. These driver warning systems include collision avoidance technology and backup, drowsy driver, and lane-keeping systems.

Crash-Avoidance Technology

The term *crash-avoidance technology* refers to motorized-vehicle equipment that includes numerous features such as adaptive headlights that improve night vision around corners and curves, forward collision warning systems, backup warning systems, emergency brake assistance, lane departure warnings, and blind spot detection.

Already in use in Europe, crash-avoidance technology debuted in the United States in 2007, when Volvo, Lexus, Mercedes, and other automobile manufacturers pioneered its use. Ford used technologies, including Driver Alert, Lane Keeping Alert, and Lane Keeping Aid, in its 2013 Explorer. The National Highway Traffic Safety Administration (NHTSA) identified 68 vehicle models that featured lane departure warning, forward collision warning, or both, in the 2012 model year, an increase from just 45 vehicle models in the 2011 model year.

Forward collision warning systems use sensors like cameras, radar, or a technology called Light Detection and Ranging (LiDAR) to pinpoint potential rear-end or head-on collisions. Some

systems have automatic braking. Volkswagen used Front Assist on the 2011 Touareg and in 2012 it introduced Proactive Occupant Protection, which closes windows and retracts safety belts to remove excess slack if the system detects potential for a forward crash.

Backup Warning Systems

The safety advocacy group Kids and Cars estimates that every week in the United States two children are killed and 48 are seriously injured simply because a backing driver did not see them. Most back-over accidents happen in residential driveways or parking lots and more than three-quarters of the time a parent or a close relative is behind the wheel. Back-over accidents are so commonplace because every vehicle has a rear blind area that can't be seen from the driver's seat. Passenger cars have a range of blind zones, depending on the size of the car and the drivers, but the blind zones behind larger, popular vehicles are uniformly large. The blind zone behind a minivan is about 25 feet and the area increases to 50 feet behind some pickup trucks.

Backup warning systems can use radar or ultrasonic transmitters and receivers, beepers, and computer systems facing to the rear of the vehicle to detect objects in its path; however, backup warning systems containing cameras that are installed within the vehicle itself work better and are widely available from several competing electronics manufacturers. With a camera system, when a driver shifts into reverse, the screen shows a wide-angle view of the rear, a view superior to the one seen through windows and mirrors.

Newer vehicles can be purchased with backup warning systems, often custom made, but drivers with older model vehicles can also have backup warning systems installed. Aftermarket cameras, that is, cameras that did not originally come with the vehicle, can be incorporated into the navigation systems of vehicles. The aftermarket camera system typically use a video screen built into a replacement rearview mirror, an added monitor for the existing mirror, or a flat screen that mounts to the inside of the sun visor.

A small video camera can be built into a license plate holder or mounted in a trailer hitch receiver or on a car's bumper. Some systems are wireless, but most feature wiring that winds through the

vehicle from the camera to the video display and to the vehicle's electric power system.

In addition to revealing children or pets, a camera mounted near or in the rear bumper can make fastening a vehicle to a trailer hitch less of a chore. A camera pinpoints the exact location of the hitch and requires far less directions and second-guessing on the part of the driver and others trying to fasten the hitch.

According to *Consumer Reports*, none of the backup warning systems is perfect. The parking sensor systems cannot accurately pinpoint every safety hazard. The systems that use a camera built into an inside mirror seem more practical because the driver looks naturally into the mirror to back up, but the view is often small or blurred and add-on mirror displays can be cumbersome. Though some cameras have narrow viewing areas and others fog up easily, a camera system is better than a beeper or a proximity sensor.

Drowsy Driver Alert Systems

A 2011 AAA Foundation for Traffic Safety survey revealed that 96 percent of the people polled believe that people should not drive when they are so sleepy that they cannot keep their eyes open, but in the same survey one-third of those polled said that they had driven while drowsy.

Drowsy driving causes more than 100,000 crashes, 40,000 injuries, and 1,550 deaths every year according to the NHTSA. Automobile manufacturers are installing drowsy driver alert systems into growing numbers of vehicles to help reduce the deaths and injuries linked to drowsy drivers. Mercedes-Benz implemented an attention assist system that creates a driving habits profile and compares it to current driving data from the car's sensors to measure the driver's alertness. When the driver deviates from his or her personal norm, the system sounds a warning chime and displays a coffee cup icon.

Audi, Cadillac, BMW, Volvo, Buick, and Saab also have drowsy driver alert systems. To determine wakefulness, Volvo's system analyzes the driver's proximity to cars ahead and whether the driver stays in the proper lane. Saab's Driver Attention Warning System uses a voice alarm. If a driver is dozing, the car announces, "You are tired." If the driver does not respond, Saab sends a second warning that says, "You are dangerously tired!"

Stop as soon as it is safe to do so!" The driver's seat also vibrates to jar him/her awake. Saab also has an onboard computer that uses facial recognition software to determine if a driver is drowsing. The system focuses night vision cameras on the driver's face to analyze slackening facial muscles and eye blinking patterns to see how long the driver's eyes stay closed between blinks. Once the system concludes the driver is sleeping, it sounds an alarm to jolt him/her awake.

Ford's technology package includes what it calls a "Driver Alert System," which warns a driver when the software detects a pattern of drowsy driving, such as weaving within the lane boundaries. For the first warning, Ford's designers chose a soft chime and then to display the dashboard message "Rest suggested." If the problem persists, a second louder chime sounds and a new message appears: "Rest now."

Second-generation drowsy driver alert systems will feature high technology. Independent companies are perfecting systems that can safely wake up a drowsing driver, including blowing puffs of air on the back of a dozing driver's neck, vibrating steering wheels, and automatic steering that guides a driver back into the correct lane. Until these technology systems are widespread and more affordable, commonsense cures like a good night's sleep will reduce accidents and fatalities.

Lane Keeping Systems

Lane keeping systems installed in cars, trucks, buses, and other vehicles can dramatically reduce accidents caused by inattentive driving, making highways safer and lowering human casualties and insurance expenses.

Lane departure warning systems work somewhat differently in different models of vehicles. Most systems have cameras that are designed to see markers used to outline road lane markings and they are capable of distinguishing between yellow and white markings. All systems use sensors that detect a car drifting out of its lane and alert the driver with a popup on the vehicle's display panel or by sounding a buzzer. If the driver does not correct the drift, the software is then supposed to engage the power steering and turn the car back toward the center of the lane.

When a driver uses a turn signal, the lane departure warning is disabled, but otherwise the warning system is active. Lane departure warnings can alert

both sleepy and wide-awake drivers that they are not paying enough attention to their position in the road. Most of the time, lane keeping systems can be found fully installed in new cars, but some companies offer systems that can be retrofitted into older vehicles.

BMW featured a lane departure warning system in its 5 and 6 series, using a vibrating steering wheel to warn the driver straying out of the correct lane. General Motors introduced its lane departure warning system to alert the driver with an audible tone and a warning indicator on the dashboard, on its 2008 Cadillac STS, DTS, and Buick Lucerne models. Volvo featured the Lane Departure Warning System and the Driver Alert Control on its 2008 model year S80, the V70, and the XC70 executive cars. Its lane departure warning system uses a camera to track road markings, along with other sensor systems designed to increase driver safety by pinpointing problems with the driver, the car, or the roadway.

Lane keeping technology has its benefits and drawbacks. As the technology advances, drivers may pay less for insurance for vehicles with lane departure systems; insurance companies usually reduce rates for drivers with special safety features in their vehicles. Lane keeping systems may be a costly initial investment, but they will reduce the cost of the vehicle over its lifetime. When the lane keeping technology works it saves lives, and its enthusiastic adherents predict that it will become the norm instead of a novelty.

The present lane keeping system technology still has its limitations, despite the increasing number of automobile technology companies that are creating and improving it. When road conditions are unsuitable, as during heavy rainfall or on curves, the lane keeping technology fails to sense highway markings and remains dormant. When the sun is at a low angle, the sensors have a more difficult time producing accurate readings.

The National Highway Traffic Administration has not yet fully endorsed lane keeping technology because its engineers and safety inspectors believe that additional evaluation and research into the lane keeping systems needs to be conducted before the administration can fully recommend it to the public.

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See Also: Automobile Accident Avoidance Systems; Automobile Accidents and Prevention; Automobile Design; Automobile Safety Systems; Automobiles, Passenger; Collision Avoidance Systems, Automobile.

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Automobile Drivers, Disabled

Disabled automobile drivers are an increasingly prevalent reality throughout the country. This fact has necessitated taking a close look at what can be done to maximize their ability to drive safely and successfully. Society has become more aware of this need and more sensitive to the situation of handicapped drivers.

The terms *disabled* and *handicapped* are virtually synonymous and are typically used interchangeably.

Both refer to individuals who are impaired in some way. The impairments can be psychological but are most often physical. Since the word *handicapped* has been used negatively in the past, the terms *disabled* and *disability* are usually considered preferable. These terms are used by advocacy organizations and can thus be taken as the current default. “Handicapped” still remains in common usage, though, and is becoming more acceptable again as it is employed in a respectful manner.

Society used to presume that disabled persons could not drive at all. As a result, those with disabilities were typically marginalized and excluded. As society has become more inclusive, there has been a corresponding understanding that physical challenges do not have to stand in the way of driving. With the right accommodations, successful use of motor vehicles can be achieved. Of course, the nature of the accommodations depends upon the nature of respective disabilities, such as impairments of vision, hearing, and physical mobility.

Vision

Visual acuity is a critical element of driving. To be effective while in transit, it is necessary to see the road ahead, other cars, pedestrians, traffic lights, walk signals, and any hazards. Not being able to see these elements well can slow a driver’s reaction time, potentially imperiling their own safety and the safety of those around them.

For this reason, drivers are examined for visual impairments before being allowed to operate a motor vehicle. Every state in the United States has specific requirements in this regard, and anyone not meeting those requirements will be denied a license. One example is Alaska, where everyone has to have at least 20/40 vision in both eyes in order to be permitted to drive. However, those with vision problems can still obtain a license if corrective lenses bring their eyes to compliance with the 20/40 standard. They are permitted to drive only when wearing the corrective lenses, ensuring that the standard is fulfilled consistently. Alaska denies driver’s licenses to individuals with visual acuity that is below 20/100 but may grant them on a conditional basis for those whose sight is tested at somewhere between 20/100 and 20/40. Conditions include a formal review by an optometrist and restrictions such as the kinds of vehicles the person can operate and the times each day when they can drive. The restrictions are

intended to protect the safety of everyone in and around the vehicle being operated.

Hearing

Hearing loss is a disability that affects people of all ages. Of course, it affects older individuals disproportionately, a fact that becomes relevant in light of the fact that tens of millions of drivers in the United States are 65 and over, according to the U.S. Department of Transportation.

The origin of hearing loss varies with each individual. It may be a result of ongoing exposure to loud sounds, from rock concerts to construction. It may also be the result of a genetic condition, such as X-linked hearing loss, which is transferred from mother to baby at conception. Lack of oxygen during prenatal development and premature birth can also be contributing factors, as can illnesses like otitis media, an inflammation of the middle ear.

Impairment of hearing loss is typically classified as mild, moderate, severe, or profound. The first two can be substantially helped with hearing aids, which may be of assistance in severe cases as well. If an individual experiences profound hearing loss, electronic devices are unlikely to make a substantial difference.

The degree of hearing loss, and the extent to which it can be corrected with a hearing aid, substantially affects a person’s ability to drive. If a person cannot hear horns of other cars, they may not get that audio warning of potentially dangerous situations. They might even not hear another car driving near them or pulling out of an adjacent parking place. Additionally, hearing loss can mean a decreased ability to differentiate between sounds and screen out unimportant ones. This can mean that individuals with hearing impairments are actually more distractible by common sounds and may therefore be at risk when driving in noisy areas.

Correspondingly, states typically test hearing as part of the licensing process. They can first test individuals without use of a hearing aid. If the person fails that test, they can try again with a hearing aid. If they meet the standard with a hearing aid, they will be granted a license that requires them to wear the hearing aid while driving. If they still do not meet the standard, it is at the Department of Motor Vehicles’ discretion whether they can operate a vehicle. If the decision is in the person’s favor, a state like New York will insist that they have a

full-view rearview mirror installed on their car or truck, because being better able to see other vehicles will compensate for lessened audio perception from hearing loss.

Physical Mobility

When the term *handicapped drivers* is mentioned, many people immediately envision drivers with physical mobility issues. This is because mobility issues are often the most visible. A person who has eye or ear problems may not be distinguishable from the general population at first glance. However, someone in a wheelchair or walking with a cane tends to be noticed immediately. Disabilities in physical mobility can include problems with hands, arms, legs, and feet. A person might have lost an arm or leg and needs to compensate with the remaining limbs when driving. Alternatively, they may have a condition, such as a clubfoot,

making manipulation of a car's gas and brake pedals a challenge. Some conditions result in individuals' having insufficient reach—simply put, they can't reach the steering wheel and the pedals simultaneously.

Fortunately, all of these challenges can be addressed through orthopedic accommodations. These can include adding devices to pedals to bring them closer to feet, or adding backing to seats to bring a person with limited reach closer to a steering wheel. They can also include left-foot accelerators for those who have lost their right leg, and vice versa.

State Departments of Motor Vehicles are not permitted to discriminate based on any of these disabilities per se. A driver's license will be granted if the person applying can demonstrate their abilities during examinations, which include road tests. Passing those tests is key: if accommodations are



This disabled driver makes use of assistive technologies, including a collapsible wheelchair model and a specially modified car, in order to drive independently. The car shown features manual braking located on the steering wheel, along with an acceleration knob, rather than floor pedals. The 60-inch access aisle reserved by the striped markings along the perimeter of the handicapped parking spot is also essential, as it gives the driver enough room to assemble the wheelchair and maneuver him or herself into it.

needed, a successful examination will result in a conditional license requiring those accommodations when driving.

Parking and Ramps

For a handicapped automobile driver, getting a license and securing any accommodations they need to drive successfully is much of the battle. However, many of them will be driving to shopping malls, schools, and business, making two other factors key to their experience. One is the presence of accessible parking places. These are designated by blue paint on parking lot surfaces and by special signs. Their requirements are established by the Americans with Disabilities Act (ADA) and enforced by the U.S. Department of Justice. Key among them is the inclusion of a 60-inch (5-foot) access aisle to accommodate the disembarking and loading of wheelchairs to and from vehicles.

The ADA also specifies requirements for wheelchair ramps. These ramps can be of tremendous convenience to drivers with disabilities as they approach and enter a building after getting out of their vehicle. Individuals who use canes or walkers can find them to be instrumental, since stairs may be difficult to manage for them. According to the ADA, ramps should have a 1:12 slope, since this gradient prevents wheelchairs from sliding backward while ascending. They should also be free of defects that might cause wheel problems or tripping.

Conclusion

Society's attitude toward handicapped automobile drivers has certainly improved. The common view toward them now is one of inclusion and acceptance. Because of that, their situation is improving in every respect. Accommodations are being developed to make driving with disabilities progressively more viable. Other people are realizing that disabled drivers simply want to travel like everyone else and that they are responsibly using the devices and tools they need to do so.

Going forward, this is likely to result in additional considerations becoming prevalent. For example, businesses will probably provide more handicapped parking spaces so all their customers will feel welcome. Ramps will also become more common, as will wider doorways that can accommodate wheelchairs without difficulty.

Some businesses may even go the next step, posting online maps of their properties so disabled drivers can quickly find handicapped parking places. Within cars, improved mirror systems and amplification devices can offer further assistance. Greater customization of cars to accommodate a variety of disabilities may also become more widely available.

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See Also: Americans with Disabilities Act of 1990; Disabled Driving and Vehicle Modifications; Elderly and Disabled Travelers; Handicapped Access; Section 504 Regulations on Accessibility.

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Automobile Drivers, Elderly

In the coming years, dramatic increases in the number of and proportion of the population that is elderly will have significant impacts on the transportation system and transportation policy. Though elderly drivers drive less than younger drivers, their impact on the transportation system may be less predictable than that of younger drivers, who are more often tied to travel patterns centered on the work commute and fixed work hours and days. In addition to the impacts to aggregate travel demand, the ability of elderly drivers to drive safely is of concern to policy makers. This latter concern has led to the implementation of screening tests for license renewals and vehicle and transportation system changes designed to limit the number of vehicle crashes caused by

elderly drivers. This may lead to the cessation of driving for some, which can lead to deterioration of mobility and greater dependence upon friends and family as well as on public services.

Over time, people in the United States and other industrialized countries have become more dependent upon the automobile for most transportation needs. As successive cohorts of drivers have aged, they have driven more frequently and for more miles than the elderly of previous generations. In addition, better health care for the elderly has allowed more elderly drivers to drive at older ages than previously. The first of the baby boom generation (the generation born between 1945 and 1964) will become elderly in the next few years. This generation has been more automobile dependent than any previous generation and therefore increases in this population will have significant impacts on the transportation system in the years ahead.

According to population projections produced by the U.S. Census Bureau, between 2015 and 2060, the number of people aged 65 years and older will increase by 93 percent (compared to 30.8 percent for the population overall). In 2060, over 22 percent of the population of the United States is projected to be aged 65 years or older (compared to 14 percent in 2010) and 612 million people will be aged 85 years or older. All industrialized countries will experience these same patterns of change, resulting in substantial increases in the number of elderly drivers. Because the growth in the population will include many more women drivers than in previous generations, questions remain as to the extent of the impacts on the transportation system.

For most age groups, the difference in driver licensure rates for men and women is less than 5 percent (with men more likely to drive than women). This is not so for the oldest age groups. Some women who drove in younger ages may give up driving as they age and their cognitive abilities and visual acuity decline. Women are also more likely to give up driving more readily as a result of deterioration of health. However, much of the gap in driver license holding between elderly men and women is primarily a result of generational characteristics.

These now elderly women had licensure rates lower than that of men during their working ages, and by 2009, 72.8 percent of elderly women and 88.6 percent of elderly men were licensed to drive. These gaps in licensure between elderly women and

men are likely to disappear as women of the baby boom generation, who have held licenses at rates similar to men, are likely to continue to drive even after entering retirement age.

Impacts on Travel Demand

Elderly drivers have both positive and negative impacts on transportation demand. For instance, most elderly drivers are no longer in the workforce and thus their travel patterns are no longer arranged around work commutes. In the aggregate, this helps alleviate peak travel time congestion. At the same time, elderly drivers may be traveling for leisure or to access other daily activities and thus help increase the amount of traffic during other than peak work commute travel times.

Driving Abilities, Safety, and Loss of Mobility

In order to efficiently and safely operate a motor vehicle, drivers must use a set of critical driving skills, many of which may decline with age. These critical driving skills influence how drivers interact with other drivers, plan trips, and maneuver on the road. As individuals lose physical and cognitive abilities, these critical driving skills may become compromised. In addition, treatments for medical conditions that may not otherwise be problematic may impact driving ability.

While the number of elderly drivers involved in crashes is smaller than the number of drivers of younger ages, on a per driver or per miles driven basis, elderly drivers have higher accident rates than all but the youngest drivers. Partly as a result of frail health prior to involvement in vehicle accidents, elderly drivers have the highest fatality crash rates on a per miles driven basis. These concerns about elderly driver capabilities and resulting higher accident rates have led to the development of laws for testing vision and cognitive ability for older drivers.

In modern industrial societies, access to a car is necessary for many daily activities, such as going to restaurants and grocery stores, health care providers, and leisure activities. In areas where public transportation may not be available or preferred for the elderly, automobile transportation may be just as important for social interactions as well. Loss of the ability to drive marks a decline in the ability to interact socially and otherwise, especially in areas where the transportation network is designed primarily for the automobile. Therefore, understanding

who nondrivers are and where they live may be an important part in planning for medical, welfare, and public transportation services.

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See Also: Automobile Accidents and Prevention; Driver Licensing; Driver Licensing Rates; Elderly and Disabled Travelers; Elderly Driver Safety Issues; Travel Patterns of the Elderly; Women's Issues/Gender Issues.

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Automobile Emissions Controls

Automobile emissions are a chief source of harmful air pollution in many parts of the world, but several technological advances have helped limit the damage caused by toxic automobile emissions. These

technologies include the catalytic converter, computerized emission control systems, exhaust gas recirculation systems, secondary air injection systems, and positive crankcase ventilation systems. Much of this technological innovation was motivated by the need to meet new environmental regulations, and as car ownership and miles driven are predicted to continue to increase around the world, such controls help mitigate the potential damage caused by increased automobile use.

Regulation

An automobile powered by an internal combustion engine using hydrocarbon fuel emits pollutants, including carbon monoxide (CO), nitrogen oxides (NO_x), and hydrocarbons (HC), during normal operation. In the early years of automobiles, they were not considered a major source of pollution because so few were on the roads. However, as automobile ownership increased, particularly in the 1940s and later, more people became aware of and concerned about the toxic substances in automobile exhaust and their effect on the environment, and technological change was largely motivated by the need to meet the legal requirements of new regulations.

In the United States, California was the first state to enact pollution controls, motivated in part by geographical and atmospheric conditions in the Los Angeles Basin that made it particularly vulnerable to smog. The Bureau of Air Sanitation, created in 1960, set standards for air quality, and the Motor Vehicle Board began to regulate tailpipe emissions. The first emission-control devices were approved in 1964, including several versions of a catalytic converter. Although these early devices were failures, they did pave the way for successful designs; the catalytic converter is now a standard emissions control device and led to regulations banning the use of lead as a gasoline additive.

The first national legislation aimed at pollution control was the 1963 Clean Air Act for America; in 1965 the Clean Air Act was amended to include regulation of automobile emissions. (The original act focused on industrial pollution.) Leaded gasoline was phased out in the United States from 1975 to 1986 to reduce lead pollution and also because leaded gasoline interfered with the operation of catalytic converters. Exhaust gas recirculation (EGR) was introduced in 1973 in order to meet

Environmental Protection Agency (EPA) nitrogen oxide emissions standards, and electronic emissions control systems were also introduced to meet EPA standards.

Emissions Control Technology

The oldest automobile emissions control device still in use is the catalytic converter, which was required on all new cars in the United States beginning in 1975 and is also used on vehicles such as motorcycles and trucks. A catalytic converter consists of a substrate, usually a ceramic or metal honeycomb; a washcoat, such as silicon dioxide; and a catalyst, usually platinum. The three-way catalytic converter is now standard for most automobiles. It converts three types of exhaust pollutants—nitrogen oxides, hydrocarbons, and carbon monoxide—into harmless substances: nitrogen oxides to carbon dioxide, nitrogen, and water; and carbon monoxides and hydrocarbons to carbon dioxide and water vapor. The first catalytic converters were called two-way catalytic converters because they did not affect nitrogen oxides.

Modern cars include a computerized emissions control system, which reduces harmful emissions and helps the car run more quietly. This system consists of an engine control computer, which receives information from a network of sensors in the car and sends signals based on that information to the car's ignition, fuel, and emission control systems. This system regulates both tailpipe emissions (hydrocarbons, carbon monoxide, etc., caused by incomplete combustion in the engine) and evaporative emissions (caused by fuel evaporation).

Exhaust gas recirculation (EGR) is a method to reduce the emissions of nitrogen oxides by recirculating exhaust gas back to the engine cylinders. By thus diluting the intake air and fuel mixture with inert exhaust gases, the peak temperature of combustion is lowered and the combustion rate slowed, thus reducing nitrogen oxide emissions, which are produced by the reaction of nitrogen and oxygen at temperatures over 2,500 degrees Fahrenheit. Early EGR methods caused loss of engine power and rough idling, but these problems have been largely solved by more modern systems integrating EGR with the spark advance system; however, some people believe that EGR reduces gasoline mileage, thus indirectly increasing rather than reducing air pollution, but this is generally believed to be a

relatively minor factor. There are several different EGR systems in use, but the most common uses an EGR valve to control the passageway between the exhaust and intake manifolds, allowing exhaust through when it is open.

A secondary air injection system improves engine efficiency and thus reduces the amount of hydrocarbons (unburned fuel) in the exhaust. Automobiles are powered by the combustion of gasoline in the presence of oxygen, so the induction chamber could be considered a primary air injection system. A secondary air injection system builds on this principle by introducing air into the exhaust system to encourage combustion of unspent fuel and also makes the car's catalytic converter work more efficiently. Aspirated air injection systems were developed first, but a pumped air injection system is the standard today.

The PCV, or positive crankcase ventilation, system is a method of controlling the toxic gases, or "blowby," from the crankcase; these gases include both unburned fuel and toxic by-products of combustion. To prevent these gases from building up in the crankcase, the PCV system introduces air into the system to flush the gases from the crankcase and route them into the intake manifold, where they can be burned by the engine. Because this introduction of air reduces power, the PCV valve is necessary to control the amount of air introduced into the system. When an engine is idling and producing little blowby, the PCV valve is nearly closed and only a small amount of air is allowed to flow through the system; when the engine is running at high speed, producing lots of blowby, the PCV valve is at its maximum opening; this control is provided through the automobile's computer system.

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See Also: Air Pollution/Air Quality; Low-Emission Vehicles; Mobile Emissions; National Ambient Air Quality Standards; Vehicle Emissions Standards; Volatile Organic Compounds; Zero-Emissions Vehicles.

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Automobile Engines

Automobiles are a ubiquitous part of millions of people's lives. However, those automobiles' engines and the agencies that regulate those engines remain a mystery to most of the public. Internal combustion engines have dominated the automobile industry since before Henry Ford saw his first motorized carriage. These engines have been popular in part because of their relative mechanical simplicity. However, this may not always be the case, as there is much pressure to develop technologies that may replace the petroleum-burning internal combustion engine. Federal agencies and acts of Congress have been put in place in response to pollution emitted by automobile engines. The Clean Air Act, the Department of Transportation, and the Environmental Protection Agency all serve to regulate, among many other things, the fuel efficiency and emissions of automobile engines.

Types

Since the introduction of the first engines at the advent of the Industrial Revolution, the vast majority of mechanical power has been generated in roughly the same way. Simply put, a power source moves either a turbine or a piston. That mechanical motion is then either directly harnessed or converted into electrical energy.

While we may see different technologies utilized in the automobiles of the not-too-distant future, at

this time the vast majority of auto engines use internal combustion engines, and most of those engines use fossil fuels. While automobiles have made great technological strides since they first came on the market in the late 1800s, the basic components of their engines remain largely intact. The average automobile's internal combustion engine operates by igniting fuel in the high-pressure, high-temperature compartment called a combustion chamber. This high-pressure ignition causes what is essentially a tiny controlled explosion. This explosion then moves a piston. The movement of that piston is turned into either mechanical energy to move the vehicle or electricity for more refined tasks. It is mechanically possible for a conventional internal combustion engine to have anywhere from one to 16 pistons (cylinders). However, the vast majority of cars have either four or six pistons, and pickup trucks and larger personal vehicles may typically have anywhere from six to 10 pistons.

Until recently, nearly every vehicle on the road possessed an internal combustion engine that burned fossil fuels (gasoline or diesel fuel). However, in our era of enhanced environmental awareness and high gas prices, the general public is starting to demand vehicles that draw power from other sources of fuel. Some of these alternative fuels may continue to operate using internal combustion engines. Examples of these include vehicles that burn ethanol, refined vegetable oil, and biodiesel. Other possibilities may include models that are entirely electrical and require no internal combustion whatsoever. These vehicles may pull their power directly from the greater electric grid, solar cells, or various types of electrical fuel cells.

Policy and Pollution

The majority of laws introduced regarding automotive engines involve pollution prevention in one way or another. American air pollution laws are by no means the strictest in the world, but they are very important on the global scale. American laws set a certain standard for vehicle emissions because automobiles gauged to American specifications are sold globally. In the United States, automotive emissions standards are managed by the Environmental Protection Agency (EPA). Relating to automotive pollution, EPA sets emissions performance standards. These standards set thresholds above which limits for conventional pollutants are set. Pollutants

regulated in this way include nitrogen oxides, sulfur oxides, and other greenhouse gases (particularly carbon dioxide).

Just as the United States sets a standard for much of the rest of the world in terms of automobile emissions, California sets standards for the United States. California's state regulations regarding automotive emissions are stricter, on average, than most of the rest of the United States. This has the effect of raising standards so that manufacturers may sell in that affluent and highly populated state. Thus, if standards are raised in California, they are effectively raised in the rest of the United States, and, thus, the rest of the world.

The greatest problem posed to society by automobiles is pollution. The vast majority of pollution from internal combustion engines is caused by incomplete combustion of fuel. Over time, engines have become more efficient at burning fuel, but only so much energy can be derived from conventional fuels with conventional engines. After combustion, conventional engines expel waste in the form of carbon dioxide, carbon monoxide, water, particulate matter (soot), nitrogen oxides, ozone, methane, and other harmful compounds. The mass release of these compounds by hundreds of millions of cars each year worldwide has detrimental results. When exposed to these chemicals, individuals may develop asthma, lung cancer, cardiovascular ailments, and other health issues. Automotive pollutants also have detrimental effects on the environment beyond humans. This includes damage to the ozone layer, acid rain, global warming, and other negative ecosystem impacts.

The U.S. Clean Air Act is by far the most influential piece of legislation in regard to automotive pollution. This act is a federal law designed to control air pollution within the United States. It was signed into law in 1963, and it was the first major U.S. environmental law to include provisions for citizen lawsuits. Additionally, the act requires the Environmental Protection Agency to enforce regulations that protect the general public from air pollution. The Clean Air Act also regulates emissions of hydrocarbons, carbon monoxide, and nitrogen oxides as well as particulates emitted by diesel engines. The act requires major stationary sources of pollution (such as power plants) to install pollution control equipment and to meet emissions limitations set by the act. Not only the



This cross-section of an internal combustion engine shows three pistons (cylinders). The majority of automobile engines have four or six pistons, but larger vehicles often have more.

users of fuels are expected to abide by EPA regulations but also those providing fuels are expected to meet certain standards. Fuel refiners, importers, and other parties in the fuel distribution system are expected to produce fuel that will contribute to lower emissions. Additionally, the act requires operating permits for manufacturers, processors, refiners, utilities, and others; these operating permits are issued by the EPA.

Since its inception, the Clean Air Act has seen its share of adjustments and amendments. In 1970, the act was expanded beyond stationary emissions sources (such as power plants and steel mills) to include mobile emissions sources, such as automobiles. These automobile standards regulate both the composition of fuel burned in the vehicle as well as emission control components within the vehicle. These standards apply to both road and nonroad engines. The 1990 amendment to the Clean Air Act

served to implement stricter standards for multiple elements of the act; these standards were to be met by 2005.

In 2010, the Clean Air Act was expanded to regulate automobile-caused global warming. The legislation was written by the Transportation Department and the Environmental Protection Agency. With this legislation, emissions and mileage standards, which will go into effect in 2016, were further refined. Under these new standards, the average new vehicle must get at least 35.5 miles per gallon toward the goal of further reducing emissions of carbon dioxide and other heat-trapping gases. Auto makers wishing to sell vehicles in the United States are expected to comply with these regulations by 2017. These regulations are expected to add \$1,000 to the purchase price of vehicles for consumers. However, the savings in fuel are expected to result in a savings of approximately \$3,000 to the driver over the life of the car.

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See Also: Air Pollution/Air Quality; Nitrogen Oxides; Noise Pollution and Cars; Sulfur Dioxide; Vehicle Emissions Standards.

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Automobile Financing

Many consumers who purchase a vehicle use some form of financing to cover the cost. The most common forms of borrowing to buy a vehicle are dealership financing, direct lending through a bank/credit union or online financial institution, a home equity loan, or a personal loan from a family member or friend.

Perhaps the biggest benefit of dealership financing is its speed and convenience. However, the associated rates and fees often are not market competitive, and buyers end up paying more overall for the up-front expediency and ease. Banks and credit unions, on the other hand, tend to offer more competitive rates and simpler loan structures, but they are more complex and time-consuming to obtain. Online financial institutions are similarly competitive with their rates and offer consumers more flexibility than brick-and-mortar lenders. The downside with online lending is the greater possibility of disreputable providers or outright scammers.

Home equity loans enable the consumer to deduct some of the loan interest from his or her tax filings, but this increases the overall financial burden and risks tied directly to the individual's home. Financing through a family member or friend comes with its own set of risks, mostly tied to the health of the relationship. While a personal loan from a family member or friend can seem simple and more flexible than other financing options, it could also cause anxiety and ill will that could damage an otherwise positive relationship.

Automobile Dealership Financing

When a buyer chooses a direct lending option, such as obtaining a loan directly from an automobile dealership or financial institution, the buyer uses the loaned funds to purchase the vehicle and becomes legally obligated to pay the amount lent plus a specified finance charge monthly or at another designated interval over a set period of time that typically ranges from three to six years.

Most automobile dealerships have an on-site Finance and Insurance (F&I) department that facilitates the loan process. The first step in the process is typically having the buyer complete a credit application that asks for personal information such as date of birth and Social Security number, details about

employment history and income sources, and data related to existing debt and credit accounts. The F&I representative uses this information to obtain a credit report of the buyer's previous and existing credit obligations and repayment history. The credit report provides details on each account held by the buyer, including the account number, account type and terms, account credit limit, recent balances, and payment activity. If applicable, the credit report also indicates a creditor summary of past-due information and any legal actions taken to collect payment on the accounts. Only a buyer who is seriously considering financing with the dealership should agree to have a credit report generated; each time a credit report is run, the individual's credit score can be lowered.

The credit report information is sent to the dealership's lenders—banks, finance firms, or credit unions—to determine which one offers the lowest interest rate for the specific buyer. The lender bases its rate on the buyer's credit report, completed credit application, and details about the terms of the sale, such as the amount of down payment the buyer will make. Buyers with a good credit history and established sources of income benefit from lower rates than buyers who have a history of late repayment, a previous bankruptcy, or very low or unstable income. In instances where buyers fail to qualify for vehicle financing on their own, a cosigner with favorable credit history and income may be required. The cosigner assumes equal responsibility for the contract, meaning that if the primary borrower cannot pay back the loan, the cosigner is obligated to make the payments.

The dealership's F&I representative typically takes the lowest approved interest rate for a buyer and adds an amount—often a percentage—that serves as the dealership's profit for selling the financing service to the buyer. As such, dealership financing is considered an add-on sale with terms outlined in a retail installment sales contract. Like most selling propositions, financing sales are subject to special offers and incentives from time to time. For example, an automobile dealership may offer manufacturer rebates or no-interest deals for a certain loan term. Such deals typically restrict who can qualify or which vehicle models are covered.

Sometimes automakers offer rebates to buyers; such rebates are cash given back to the buyer as an incentive to purchase a certain vehicle. These

types of offers often are used to help clear excess inventory when sales are slow for a particular vehicle model. Manufacturer rebates are separate from the dealership's financing package and can be applied—or not, at the buyer's discretion—to mitigate the cost of the down payment at the time of purchase.

Another financing-related sales tool used by automobile dealerships is 0 percent interest offers. To qualify for no APR (annual percentage rate) on financing, buyers generally must agree to stricter loan terms. For example, buyers may need to accept a shorter financing term of three years or less. The compressed loan cycle means that repayment installments will be much higher. In addition to shorter loan terms, buyers who want to take advantage of no-interest financing must meet stringent credit criteria and have a credit score of 680 or higher. The dealership offers tied to no APR often are limited to actual vehicle inventory on the lot and do not include the opportunity to special-order desired features.

In cases where a manufacturer rebate also is offered on a selected vehicle, the buyer seeking no-interest financing generally has to give up the cash rebate, and vice versa, as only one special offer typically applies. Sometimes it is more beneficial to the buyer to obtain the rebate and secure financing outside the dealership, especially since many dealerships ultimately sell their loan agreements to external financial lenders. The lenders take over the financing contract with the buyer and manage the details of loan administration.

Other Sources for Automobile Financing

Buyers also have the option of going directly to independent financial lenders for their vehicle financing. Even if the buyer decides to accept dealership financing in the end, it may be beneficial for potential purchasers to research other loan options beforehand so they can make more informed financing decisions. The logical starting point for the buyer is his or her own bank. Most banks provide preliminary information about vehicle loan rates and other loan costs to their customers in person or over the phone. If the customer wishes to proceed with obtaining a more formal quote for a vehicle loan, much of the required credit application information is already in the bank's system, which can help hasten the credit decision process.

Online financial institutions offer similar opportunities for vehicle loan information and quotes. Individuals can type their personal details and loan preferences into an online form to receive instant data and cost estimates for vehicle financing. Before entering any personal information online, buyers should be sure to confirm the organization's legitimacy through aggressive research, including calling one or more of the telephone numbers listed on the site, and to verify that the site's online forms are protected with security software and privacy policies, which are usually indicated clearly on the site. Reputable online lenders can provide very competitive vehicle financing rates.

Credit unions also offer automobile financing services, often at lower interest rates than banks or dealerships. The main catch for this type of financing is that many credit unions require loan recipients to be members of the credit union. Those who qualify for membership may be able simply to open a small checking or savings account with the credit union to be eligible for the institution's low-interest vehicle financing.

Buyers can use the information and quotes gleaned from a bank, online financial institution, or credit union to serve as a reference when considering financing through an automobile dealership program. Buyers should take detailed cost and interest-rate information from their research with them to the dealership to compare APR, loan structure and terms, associated fees and prepayment penalties, and other elements of the financing.

Homeowners have the additional option of obtaining a home equity loan. A home equity loan borrows from the home's accumulated equity—the difference between the amount owed and the amount at which the house is assessed—to provide cash that the homeowner can use to fund large purchases like major home improvements or a new automobile. Homeowners typically can deduct in their tax filings some of the interest paid on a home equity loan. Such loans also offer better rates in some cases than a straightforward vehicle purchase loan.

Automobile purchasers who discover and secure a good financing option before they visit the dealership can shop as a cash buyer, using the prearranged funding as the cash for outright purchase and repaying the external lender rather than the dealership.

Assessing Affordability

Before any buyer begins shopping for a new vehicle, he or she should determine overall affordability. Specifically, buyers need to know how much money they can afford to pay each month on a vehicle loan. Working backward from there, buyers need to perform some research to estimate anticipated loan term, financing and interest rate fees, and other associated loan costs to come up with a maximum price they can afford for vehicle purchase. Buyers should also consider any savings they intend to use as a down payment for a vehicle and whether they plan to trade in another vehicle as part of the new vehicle purchase. Knowing which assets will be applied and capping the purchase price at a manageable level prior to visiting a dealership will help buyers narrow their search and negotiate the most appropriate financing for their individual circumstances.

Key Regulations

Several federal laws are in place to help regulate automobile financing. The Equal Credit Opportunity Act bars discrimination in credit lending based on age, gender, race, religion, color, marital status, national origin, receipt of public assistance, or activation of rights under the federal Consumer Credit Protection Act. The Fair Credit Reporting Act provides consumers with the right to one free credit report annually and establishes a process by which consumers can dispute information in their credit file. The Truth in Lending Act requires that creditors provide loan applicants with written disclosure of important terms of the credit agreement such as APR, total finance charges, monthly payment amount, payment due dates, total amount being financed, length of the credit agreement, and any charges for late payment prior to the buyer signing the contract.

If a potential cosigner is part of the loan agreement, the Credit Practices Rule requires creditors to provide written notice to all cosigners about their liability for payment should the borrower fail to pay.

Broad Economic Impact

Every vehicle purchase has economic implications beyond an individual's personal finances. The automotive industry in the United States relies on vehicle sales to drive business and jobs, not just at the dealership but also at automobile design firms,

manufacturing plants, parts and accessories suppliers, maintenance and repair shops, gas stations, and other enterprises directly related to vehicle purchase and use. Indirectly, a host of other industries also rely on vehicle sales to support their success. Financing, marketing, and travel are just a few of the peripheral sectors that are greatly influenced by trends in automobile sales.

Robust vehicle sales potentially mean more business for more companies across the United States, helping maintain healthy employment levels and a strong U.S. economy overall. The reverse, however, is also true.

Shari Parsons Miller
Independent Scholar

See Also: Automobile Culture; Automobile Design; Automobile Industry, Economics of; Automobile Insurance; Automobile Manufacturing and Sales; Automobile Costs of Operating; Automobiles, Passenger; Car Sharing; Travel by Mode; Vehicle Ownership Models.

Further Readings

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allowed the United States to become the largest automobile producer for much of the 20th century, although it was overtaken in this role by Japan during the 1980s. Though it is still one of the largest domestic manufacturers, the automobile industry suffered from financial problems beginning in the 1970s due to various factors. These factors included rising petroleum prices, increased competition from foreign automakers, changing consumer tastes, and an inability to deliver products that were reliable and fuel efficient. Culminating in the financial crisis of 2008, two of the United States' "Big Three" automakers needed government loans and investments to survive. The size of the automobile industry, and its importance to the U.S. economy, suggests that its financial health remains a matter of interest to many.

Early History

By the 1880s, the horse-drawn buggy provided many Americans with a reliable and consistent means of transportation. Technological developments that resulted in smaller, more efficient, and less expensive battery-powered electrical, internal combustion, and steam engines resulted in the development of a nascent automobile industry during the following decades. In the 1890s, hundreds of automobile manufacturers sprang up, although many of these built only a handful, sometimes even a single, vehicle. Ransom E. Olds was the first automobile manufacturer able to use the mass production process. Olds, who introduced his Oldsmobile in 1901, had sold over 3,700 automobiles by 1903. Other manufacturers also began to mass produce automobiles, and the industry became a major source of employment.

While many decry government subsidies for the automobile industry, it has received economic support—directly or indirectly—from the public purse almost since the beginning. In its infancy the automobile industry was severely constrained by the paucity of appropriate roads. While certain cities, towns, and villages had paved roads within their boundaries, most travel of any distance was conducted via rail or waterways. Those roads that existed between cities were mostly dirt surfaces and difficult to traverse, especially in inclement weather. To alleviate this problem, the U.S. Congress passed the Federal Aid Road Act of 1916, which provided \$75 million to build roads that were suitable for

Automobile Industry, Economics of

Developed in the 1890s, the automobile industry rapidly evolved into a major engine of the U.S. and global economies. The size of the U.S. domestic market, coupled with a wealth of natural resources,

automobiles. This act proved so popular that it was augmented by the Federal Aid Highway Act of 1921, which provided additional road construction monies. As a result of these subsidies, by 1924 the amount of paved road in the United States had increased to over 30,000 miles, creating a means and a market for automobiles to travel distances.

Olds was joined by a variety of other competitors. Henry Ford, who had begun building cars in 1896, started to manufacture automobiles under his own name in 1903. In 1913, the Ford Motor Company was the first car builder to use a conveyor belt-based assembly line, allowing it to use the economy of scale provided by mass production to lower the price of its Model T automobile, first introduced in 1908. Although originally costing \$850, the price of a Model T had declined to \$290 by 1924. This reduction in price made the Model T extremely popular, selling over 15 million units in total, and helped the Ford Motor Company grow into the United States' largest automobile manufacturer by the late 1920s.

William Durant had taken control of the Buick brand and later acquired Oldsmobile and another brand to form General Motors Corporation (GM) in 1908. After Durant was ousted from General Motors following a board coup, he founded the Chevrolet Motor Company and later retook control of the General Motors Corporation. Under Durant's successor, Alfred Sloan, General Motors grew to become the world's largest automaker. Under Sloan's leadership, General Motors came to develop highly decentralized management. Each of the corporation's divisions produced a different type of line aimed at a different segment of the auto-buying public. Chevrolets, for example, were aimed at entry-level buyers, while Cadillacs were made for high-income purchasers, with other makes, such as Pontiac, Oldsmobile, and Buick, each aimed at different demographics. To facilitate the purchase of its vehicles, GM started the General Motors Acceptance Company to help consumers finance the purchase of its automobiles. GM expanded overseas during the 1920s, purchasing the United Kingdom's Vauxhall Motors Ltd. and Germany's Adam Opel AG, which allowed it to continue to compete with Ford, which had also expanded overseas during this era.

Walter Chrysler had worked with Durant at General Motors, heading the Buick division before

resigning in 1919. Hired to lead flagging competitor Willys-Overland Motor Company in 1920, Chrysler left that manufacturer over a dispute and took over the Maxwell Motor Corporation, which he reorganized into the Chrysler Corporation shortly thereafter. Purchasing the Dodge Brothers Company in 1927, Chrysler significantly expanded production and sales during the 1920s, becoming the second-largest automobile manufacturer behind General Motors during the 1930s by introducing several other makes, including the Plymouth and the DeSoto.

Although Chrysler was innovative in introducing an aerodynamic design for its cars in 1934, this innovation was rejected, causing the company to embrace conservative styling for the next several decades. With GM and Ford, Chrysler was one of the three largest automobile manufacturers that dominated American sales, known informally as the "Big Three."

A variety of smaller automobile manufacturers were busy through the 1920s, with many targeting niche markets. The high-end luxury sector included the Duesenberg Motor Company, the Peerless Motor Company, the Pierce-Arrow Motor Car Company, the Stutz Motor Company, and others. Smaller companies were also responsible for many innovations during the 1920s: the Franklin Automobile Company experimented with air-cooled aluminum engines, and the Auburn Automobile Company introduced front-wheel drive on its Cord automobile and other innovations. Although popular with sectors of the car-buying public, most of these smaller car companies did not survive the Great Depression and ceased doing business by 1940. In addition to the Big Three, only a handful of smaller automobile manufacturers survived the Great Depression. Those companies that survived included Crosley Motors, the Hudson Motor Car Company, the Packard Car Company, Nash-Kelvinator Corporation, and the Studebaker Corporation.

The Depression saw a huge contraction of the American economy, with unemployment rates rising to as high as 25 percent. As a result of this downturn, automobile sales plummeted, and many smaller companies were unable to survive. These troubles also affected the Big Three, and unemployment rates near Detroit, Michigan, exceeded 30 percent. Low-skilled laborers were often the

first to be laid off by the automobile manufacturers. Although the automobile companies made some small attempts to assist the terminated workers and their families, for the most part they were left to their own devices. These problems, coupled with the difficult environments in which the workers had to toil, made the situation ripe for labor unions. The United Auto Workers (UAW) worked to build a membership base and was recognized by General Motors and Chrysler by 1937. Although it attempted to hold out, Ford joined its competitors in agreeing that its employees be represented by the UAW. This representation led to significant changes in employment conditions, and benefits such as pensions and medical insurance began to be offered. The cost of these benefits would later prove a difficult problem with which the automobile manufacturers had to deal.

World War II

On December 7, 1941, the Imperial Japanese Navy launched an aerial attack on the U.S. naval base at Pearl Harbor in Hawaii. As a consequence of this attack, the United States declared war on Japan the next day and thereby entered World War II. As a result of this action, all automobile manufacturers were required to participate in the war effort, which entailed manufacturing a variety of other vehicles, including tanks and aircraft, while also producing a variety of other weapons. Because of this transformation, passenger automobile manufacture was halted in February 1942. Although the manufacturing processes of the automobile companies were devoted to war-related orders, the factories and other offices were under the control of company management. In consultation with the military, the automobile manufacturers spent most of the next four years involved in wartime production.

Although the automobile manufacturers had been producing war-related orders before Pearl Harbor, the scope and scale of wartime production was staggering. Production levels of the auto manufacturers often doubled or increased at an even greater amount. Many factories were enlarged to keep up with this demand, and many new factories were constructed, all of which would be reconverted to automobile manufacture after the conclusion of the war. Hundreds of thousands of new employees were hired by the automobile manufacturers to meet the

demands of the war effort, and new manufacturing techniques were learned. Because the automobile companies were able to produce aircraft and other newly engineered products, the leaders of the industry were able to acquire a variety of improvements due to new manufacturing processes.

Postwar Production

In the year immediately following the conclusion of World War II, the automobile industry was strangely quiet, as factories were rapidly retooled for a return to domestic production. Once this process was complete, however, the pent-up demand caused by nearly five years of no new automobile production caused sales to soar. Before the war, the Big Three had controlled slightly more than 70 percent of automobile production in the United States. During the 1950s, their market share sometimes reached nearly 95 percent. This consolidation furthered the influence that the Big Three exerted over the industry. Other factors that influenced the success of the automobile industry during the 1950s included labor unrest, the burgeoning civil rights movement, and fierce competition for customer loyalty.

Returning servicemen helped build the market for automobile sales. During the 1950s, nearly 60 million automobiles were sold in the United States, amounting to one vehicle for every three individuals. Reflecting the overall prosperity being experienced by the United States, American-built automobiles became larger and more powerful in the postwar era. The V8 engine, which had been introduced to the general market during the 1930s by Ford, proved very successful with consumers. An internal combustion engine with its cylinders and pistons aligned in a V shape, the V8 engine employs 8 pistons to drive a common crankshaft.

Because the V8 could fit in the same engine compartment as a V6 engine, automobile dealers were able to increase their profits by selling the larger engine as an upgrade to the standard model. Coupled with a strong advertising campaign, the V8 was popularized in film and song, and demand for the engines soared. GM introduced a V8 engine in its Oldsmobile and Cadillac models in 1949, and Chrysler introduced its own Hemi-head V8 in 1951. For the better part of the next three decades, car companies fed consumers' interest in power by building ever larger V8 engines.

The popularity of larger size demonstrated by the soaring sales of V8 engines was mirrored in growing automobile bodies. Cars became longer, lower, and wider as increasingly powerful engines could easily power the greater load. Reflecting the prosperity most workers were enjoying, automobiles became more expensive and luxurious during this decade as well. In keeping with the fascination with the space race between the United States and the Soviet Union during the 1950s, cars began to more closely resemble airplanes. Rear fins appeared on many automobiles and grew ever larger as the decade progressed. Bumpers, lights, and chrome decoration all appeared on automobiles during this decade.

Automakers began to offer rapidly changing features and innovations, introducing a new feature and then retiring it after several years. This practice, known as planned obsolescence, appealed to consumers' interest in new and convenient features that promised to make their ride more comfortable. Because the features and designs changed rapidly and regularly, however, cars appeared dated within only a few years so consumers were often eager to trade in their vehicles for new models. Some features focused upon safety while others, such as the rear fins, appealed only to a sense of style. But this constant and continual changing of design helped build consumer desire for new cars, creating an economic model that depended upon frequent purchases of new vehicles. This economic model led American automakers to focus upon cosmetic appearance and innovative features rather than upon durability or dependability of the automobiles produced.

Certain features, such as automatic transmissions and power steering, made automobiles easier to drive and were highly appealing to many consumers. As automobiles grew increasingly larger, automatic transmissions and power steering made them easier to operate. Although the automatic transmission had been developed during the 1930s and first introduced on a 1940 Oldsmobile, the advent of World War II had prevented it from being heavily marketed until the postwar era.

The automatic transmission changes the gear ratios of the automobile as the vehicle moves with no action necessary by the driver. This differs from a manual transmission, which requires a driver to shift the gears manually while driving. Used on

tanks during the war, automatic transmissions were trumpeted by GM as being "battle tested" when they again became available during the 1950s.

Since the automatic transmission makes a vehicle easier to drive, it was marketed to consumers for two primary reasons. For one, the automatic transmission permitted the driver to concentrate more fully on navigating the vehicle, so it was seen as enhancing the safety of a trip by preventing distractions that would otherwise divert his or her attention. In addition, the automatic transmission made the vehicle easier to drive, as it eliminated the need to learn how to operate a manual transmission. As the automobile companies were trying to appeal to as many buyers as possible, the chance that a vehicle could be used by other than experienced drivers was often persuasive as this increased the potential market for the automobile that included the option or options that made it more accessible.

The decision to pursue customers who desired ever-changing features and innovative and changing designs began the strategy known as "planned obsolescence," whereby automobiles were designed to have a limited useful life span after which they became unfashionable and needed to be replaced with a new model. The practice of introducing new automobile models annually is part of this strategy, which initially proved highly profitable for American automakers but which would eventually have negative repercussions that affected their economic health.

Power steering was another innovation that appealed to drivers for multiple reasons. Because power steering augments the driver's efforts in turning the steering wheel by providing hydraulic support, it requires only slight effort to turn the wheel and makes it much easier to turn the steering wheel even when a vehicle is moving slowly or stopped. First available on the 1951 Chrysler Imperial, power steering was soon adopted by GM's Cadillac. Power steering initially added about \$200 to the price of a new vehicle, which increased the manufacturer's profits and increased the motivation to include it on automobiles. Power brakes, which use a vacuum booster to multiply the effort the driver exerts while stopping the car, also were first introduced as an option during the 1950s, with upscale makes such as Buick, Mercury, and Edsel (Ford) making these available to consumers for an upgrade in cost. Again, the option provided convenience and ease



A worker assembling an automobile hood in the General Motors (GM) Fairfax Assembly Plant in Kansas City, Kansas, in August 2012. Spurred by the near collapse of U.S. automakers GM and Chrysler after the financial crisis that began in 2008, the U.S. government invested more than \$62 billion in the two companies, as well as \$18 billion in GMAC and Chrysler Financial.

for the driver while also appealing to many consumers' desire for safety. As an option, it permitted manufacturers to increase profits while also underwriting the development of new features.

Some options, such as air conditioning and in-car radios, were marketed purely as a luxury experience while others, such as seat belts, appealed only to those concerned with safety. Automobile air conditioning, which could cool air and eliminate humidity from the passenger compartment of a car, was especially popular in the south. Though a number of companies had experimented with automobile air conditioning before the war, in 1953 Chrysler sold the first vehicles offering this as an option. A decade after it was introduced, nearly 25 percent of cars sold in the United States contained air conditioning.

Radios had long been available in automobiles, but because they utilized vacuum tubes that often broke, they were frequently out of service. By the mid-1950s Chrysler first offered an all-transistor radio as an option. More reliable than tube radios, the option became popular, unlike a miniature in-car phonograph that Chrysler introduced about the same time. Seat belts, also first offered as an option during the 1950s, were initially not very popular with drivers. These became standard equipment only after legislation made them required on all vehicles.

During the 1960s the federal Interstate Highway System, begun in 1955, was beginning to increase the demand for automobile travel. This, coupled with the growth of suburban areas, increased the need for automobiles. The Interstate Highway

System was highly popular with, and heavily supported by, executives in charge of the American automakers. There were two reasons for this support. First, increasing the number of highways also increased the market for automobiles, thus creating an ever expanding market for the automobile companies. Second, because the costs of the Interstate Highway System were borne by the taxpayers, this gave those who chose to travel by automobile a cost savings compared to railway travel, which required the railroads to build and maintain their own tracks, which increased the price of tickets.

Families began to purchase a second automobile, something that seldom occurred even a decade before. For this reason, a market developed for smaller automobiles. To support this market, and to compete with compact imported cars that were beginning to appear, the Big Three began developing smaller models. Ford debuted the Falcon during this decade, and Chevrolet introduced the Corvair, and Plymouth the Valiant. These cars were less successful than a group of sporty cars that became popular, beginning with Ford's Mustang, introduced in 1964. Automobiles of this class, known as "pony cars," were popular and the Mustang spawned a host of similar models, including the Chevrolet Camaro and the Dodge Challenger. "Muscle cars" also became popular during this decade, models that combined a powerful engine with a mid-sized body. Popular models included the Pontiac GTO, the Dodge Charger, and the Ford Torino. Although these cars remained popular throughout the late 1960s, high insurance rates on these automobiles greatly diminished their popularity after a few years.

Government regulations, which had not occurred with much frequency before the 1960s, also became more common during this decade. Public concerns regarding safety and environmental protection caused the development of a regulatory system with which the automobile industry had to comply. Beginning in 1962, many states began demanding that new vehicles contain seat belts, which originally were lap belts. After studies suggested these lap belts could cause injuries under certain circumstances, the National Traffic and Motor Vehicle Safety Act of 1966 set standards intended to protect public safety. The changes demanded by these standards were many. Beginning in 1968, front-seat passengers needed to be

provided three-point seat belts, front-seat headrests became mandatory, steering columns had to meet energy-absorbing criteria, interior features such as dashboards required padding, ignition key warning systems needed to be installed, and marker lights needed to appear on the sides of vehicles.

These safety regulations were enacted concurrently with a variety of laws and regulations intended to protect the environment. After the U.S. Congress passed the Clean Air Act of 1963 and the Vehicle Air Pollution and Control Act of 1965, auto emissions became regulated for the first time. Beginning in 1968, emission controls began to be used, and leaded gasoline began to be phased out during the early 1970s. Newer vehicles needed to comply with the mandate to use unleaded gasoline, which resulted in the use of lower compression engines. The lower-compression engines resulted in lower horsepower and performance, which removed two areas of strength for American carmakers in their battle against imported automobiles. By the end of the decade, new automobiles required catalytic converters, which further impeded performance. By the mid-1970s, the era of dominance by the Big Three was over.

Labor Issues

The automobile industry was not completely unionized until Ford recognized the United Automobile Workers (UAW) in 1941, following Chrysler and GM, which had done so in 1937. Founded in 1935, the UAW was able to organize quickly and use the sit-down strike to gain concessions from the automakers. Walter Reuther, the longtime head of the UAW, was a socialist who fought for social changes above and beyond contract matters. The UAW was among the first labor unions that accepted African American members. Reuther developed the UAW into a disciplined and responsible organization that was able to gain tremendous concessions from the automobile manufacturers, concessions that later negatively affected their economic well-being.

During World War II, the UAW's rank and file made a "no strike" pledge, a move designed to ensure that the war effort would be able to proceed at full force. This no strike pledge ensured that strikes would not interfere with the production of weapons, aircraft, tanks, and other needed material. Immediately after the conclusion of the war,

however, the UAW again began using the strike as a bargaining tool. In negotiations with GM, Reuther sought a greater voice in management decisions for workers, a position that GM resoundingly opposed. To that end, Reuther led the UAW workers in a 113-day strike against GM, although he was ultimately unsuccessful in his efforts to get GM to agree to power sharing. The UAW was able to extract an 18-cent-per-hour rise in wages. This increase, although large at the time, did not satisfy the more radical members of the UAW, who then sought implementation of a 30/40 scheme: a 30-hour workweek compensated by 40 hours of pay. Reuther rejected the push for 30/40 and instead concentrated on gaining paid vacations for members and increased annual pay. As this was obtained, the UAW next sought additional increases in benefits, such as pensions and medical health care insurance.

The high level of competition between the Big Three during the 1940s and 1950s permitted the UAW to exert economic pressure on the auto manufacturers in order to gain the concessions it sought. After the UAW's executive board decided upon the next goal for its membership, Reuther selected one of the Big Three and demanded this concession in its next contract. If the automaker refused, the UAW members at that company went on strike, effectively shutting it down while its two competitors divided its market share. Once the original target capitulated, the UAW then demanded the same concession from the other two carmakers, which capitulated rather than go through the same process.

In 1950, the UAW negotiated a contract with GM that would shape labor relations within the automobile industry for decades to come. At that time, Reuther negotiated a five-year contract that came to be known as the "Treaty of Detroit." According to the contract, the UAW members pledged not to strike during the five-year duration of the agreement, which provided the automakers with increased security. In exchange, Reuther extracted a wage and benefits package that was considered staggering at the time. GM workers were provided with extensive health and pension benefits, increased wages, increased vacation time, cost of living adjustments to wages, and supplemental unemployment payments in the event of a layoff. This wage and benefit package was soon adopted by Chrysler and Ford, and many of the Big

Three's smaller suppliers also adopted these benefits for their employees.

While the Treaty of Detroit provided American autoworkers with one of the highest standards of living in the world during the 1950s and 1960s, it later came to represent an economic burden on the automakers and even on the UAW membership. By the mid-1970s, competition from European and Japanese carmakers had increased significantly. Because many other nations provided pensions and health care via national programs, the pension and health benefits provided by the Treaty of Detroit placed the Big Three at a competitive disadvantage with regard to the other manufacturers. As a result, when the Big Three built new plants, they often chose to do so outside the United States, as this would save them the cost of pensions and benefits. These cutbacks greatly affected the membership of the UAW, which had been more than 1.5 million members in 1979, but which had fallen to approximately 380,000 active members by 2013.

Oil Embargo to the Present

Beginning in 1973, the Organization of Petroleum Exporting Countries (OPEC) declared an oil embargo against the United States due to opposition to U.S. foreign policy in the Middle East. As a result of this action, the price per gallon of gasoline soared, and larger American-made cars and trucks were suddenly at a competitive disadvantage compared to smaller, fuel-efficient imported automobiles. In an effort to spur more efficient automobiles, the U.S. government mandated that the miles per gallon (mpg) of cars in an automaker's fleet average 18 mpg by 1978, rising to over 27 mpg by 1985. This caused the Big Three to take radical action, with GM downsizing its entire model line in 1977 and with all manufacturers introducing smaller, more fuel-efficient cars.

Unfortunately, the speed with which the Big Three adopted these changes resulted in a sudden and considerable decline in quality control and customer satisfaction. As a result, the Big Three's market share declined precipitously at a time when it also was required to devote more revenues to the research and development of new models. Increased foreign competition made it necessary for American automobile companies to offer incentives to encourage consumers to purchase their products.

These incentives included “rebates,” which amounted to cash refunds issued to those who purchased new cars and below-market interest rates offered through finance companies controlled by the automakers, such as General Motors Assurance Corporation (GMAC), Chrysler Credit Corporation, and Ford Motor Credit Company (Ford Credit). Although these plans increased sales, they damaged the automakers’ profitability and proved impossible to sustain over time.

The Big Three’s troubles benefited many foreign automobile manufacturers but especially the Japanese. Toyota Motor Corporation, Honda Motor Company, Nissan Motor Company (Datsun), and others saw their sales soar. During the 1980s the market share of foreign automakers grew rapidly and further hurt the sales and image of the Big Three. In response, GM, Chrysler, and Ford sought to increase their expertise, which resulted in investments by the American automakers in Isuzu Motors Ltd., the Mitsubishi Group, and Mazda Motor Corporation, respectively. These investments resulted in a variety of new models, some made overseas but branded with American nameplates. After the price of oil declined by the mid-1980s, the fortunes of the Big Three revived. Chrysler introduced its hugely successful minivan, Ford enjoyed critical success with its revitalized aerodynamic styling, and GM invested in new technology designed to lower the costs of production.

During the 1990s, the spike in oil prices caused by the Gulf War weakened automobile sales and resulted in temporary operating losses, although the Big Three had again rebounded by mid-decade. As fuel prices declined, the sales of large sport utility vehicles (SUVs) and light trucks soared. As SUVs and trucks are among the most profitable of models for the Big Three, all three did well during the decade. In 1998, German carmaker Daimler-Benz AG purchased Chrysler, a “merger of equals” that ultimately proved unsuccessful and resulted in Chrysler being spun off to a private equity firm in 2007.

Although GM began experimenting with the EV1, an electric-powered car that it offered for lease to the public from 1996 until 1999, followed by the Gen II successor vehicle, the program was ultimately canceled in 2003 due to slow sales. This decision, especially following billions of dollars of investment in the program, was to prove harmful not only to GM but also to the American auto industry as a whole.

While automobile sales rebounded quickly after the 2001 recession, the stock prices of the Big Three lagged as fears about unfunded pension liabilities drove down the value of the manufacturers, which in turn required significant additional contributions to the pension funds with monies that were sometimes borrowed. Once fuel prices began gradually rising in 2005, sales again were negatively impacted. To counter this, all of the Big Three began depending more upon their subsidiary businesses to generate profits to offset losses in auto manufacture. As a result, for example, GMAC was to enter the home mortgage market, a decision that later proved unwise.

During the economic crisis of 2008 the Big Three, already in weakened condition, saw sales decline precipitously. In November 2008, the chief executive officers (CEOs) of the Big Three flew to Washington, D.C., to request government aid from Congress, a request that was denied. By December, President George W. Bush provided GM and Chrysler with \$17.4 billion from the Troubled Asset Relief Program (TARP). Ford, which had raised \$23 billion in cash in 2006, did not receive any funds from TARP. By spring 2009, both GM and Chrysler filed for Chapter 11 bankruptcy protection, causing President Barack Obama to form the Presidential Task Force on the Auto Industry to decide how best to support these failing companies, if at all.

After determining that GM and Chrysler were “too big to fail” because of their importance to the U.S. economy, the United States government provided a significant bailout to the automakers to ensure their continued operation. Billions of dollars in shareholder equity were wiped out as a result of this takeover. Once operated by government appointees, both GM and Chrysler engaged in many cuts, such as closing production factories, closing hundreds of dealerships across the nation, and eliminating thousands of jobs.

The revitalized companies also asked for, and received, numerous concessions from the UAW, permitting them to lower the cost of production significantly. GM shut down its Pontiac, Hummer, and Saturn brands and sold its Saab division. Chrysler was given new management from Italian automaker Fiat SpA, which also received an ownership stake in the carmaker. In total, the U.S. government invested over \$62 billion in GM and

Chrysler, in addition to an additional \$18 billion given to GMAC and Chrysler Financial. Operating on a smaller scale, GM, Chrysler, and Ford began enjoying increased sales and financially better footing by 2014.

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See Also: Automobile Culture; Automobile Design; Automobile Financing; Automobile Manufacturing and Sales; Automobiles, Passenger; Clean Air Act and Amendments; Commuting; Environmental Impacts; Highway Finance; Intelligent Vehicle Highway Systems; U.S. Department of Transportation.

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began in the Northeast. Connecticut adopted a law in 1925, when automobile ownership was first becoming popular, requiring any vehicle owner involved in an accident to provide proof of financial responsibility in order to be allowed to continue driving. That same year Massachusetts refined this to a requirement to purchase liability insurance as a precondition of registering an automobile in the state. For 30 years, however, it was the only state to require insurance, until New York made insurance compulsory in 1956, followed by a wave of most other states.

Terminology may vary from provider to provider, but various forms of coverage include coverage for physical damage to the vehicle in the event of a collision, damage to the vehicle from some other cause (such as fire or flood), theft of the vehicle, maintenance and repairs to the vehicle, the cost of renting a car during the period when the damaged insured vehicle is being repaired, the cost of towing the vehicle to a mechanic to be repaired, damage to other vehicles in a collision, damage to property caused by the collision or by the vehicle, injury to the insured party, injury to parties in the other vehicles in a collision, and injury to passengers in the insured automobile. Typically, the insured party is required to pay a deductible in the amount determined by the insurance policy. The insurance company pays the costs in excess of the deductible amount, based on the specific damages and benefits covered by the insured's policy, up to a predetermined maximum.

Nearly every state requires that every vehicle owner carry a certain level of liability insurance, which covers the damage done to other vehicles in the event of a collision for which the driver is at fault, and often covers property damage incurred by the insured driver. A small number of states permit vehicle owners to opt out by paying an alternative fee that partially offsets the cost of uninsured drivers' involvement in accidents in the aggregate. More commonly, states require greater insurance coverage. In states that require insurance, proof of insurance is expected to be kept in the car at all times. In many states, cars that are financed through car loans from a bank or other lending institution require a greater level of insurance to ensure that the bank will be able to reclaim the value of its loan in the event the car is damaged or destroyed.

Automobile Insurance

Automobile insurance provides insurance against the costs of automobile accidents, theft, or damage from other causes. Various forms of coverage are available, and the level of insurance required of a driver or vehicle owner varies from state to state. The legal framework establishing financial responsibility in the event of vehicle accidents

Collision coverage is the most basic form of insurance coverage beyond liability, and it provides coverage for accidental collisions. Though it is a common form of insurance because of its practical benefits to the owner, it is not commonly required by states unless the car is financed. Comprehensive insurance, which is rarely required even for financed cars, provides coverage for damage caused by events other than collision, including weather damage, fires, vandalism, and “acts of God,” which are understood to be disasters without human agency. Uninsured or underinsured motorist coverage provides coverage to the insured if he/she is in a collision in which the other party is at fault but either lacks the insurance coverage to pay the insured party’s bills or is insufficiently insured. Although liability insurance is required, it is common in much of the country for a percentage of drivers to cancel their liability insurance policies after registering their car, and so collisions with uninsured drivers occur with nontrivial frequency.

Uninsured motorist coverage is required by some states. Nearly half of the states limit the damages that can be paid by uninsured motorist coverage.

The insurance requirement is usually enforced by requiring proof of insurance to be provided when a car is registered and at its periodic safety or emissions inspection, if applicable. Some states require proof of liability insurance before a driver’s license will be issued. California and New Jersey provide additional incentive to purchase insurance by permitting only insured drivers to pursue claims for pain and suffering from injuries sustained while driving.

In addition to the insurance requirement in so many states, car rental agencies have various policies. Some will only rent to drivers who are already insured. Others may allow uninsured drivers to purchase insurance from the rental agency for the duration of the rental period. Others may require a minimum level of insurance greater than the minimum required by the state. Still others



Drivers wait for assistance after a minor automobile collision in Tokyo, Japan. Insurance coverage became compulsory for drivers in most U.S. states in the mid-1950s. Today, nearly every state requires liability insurance, which covers the damage done to other vehicles in the event of a collision for which the driver is at fault, and often covers property damage incurred by the insured driver.

impose requirements that differ based on the age of the driver. Most rental agencies, for instance, will not rent to drivers younger than 21 because of restrictions imposed on them by their own insurance policies. In some states they do not rent to drivers under age 25, and even where they do, this is often not widely publicized—drivers under 25 can usually rent only by paying a significant extra fee. For instance, Advantage, Avis, Budget, Dollar, Enterprise, Hertz, National, and Thrifty now allow drivers aged 21–24 to rent a car in states that permit them to do so for an additional fee of an average of \$25 per day, depending on the vehicle class being rented.

There are exceptions to those general rules. New York and Michigan require that all drivers over 17 be eligible to rent automobiles, though they place no limit on the extra fee that can be charged to them, which in both cases is higher than the fee charged to people aged 21–24 in most other states. Military and federal government officials 18 and older renting a vehicle while on business, and drivers 18 and older insured by USAA (United Services Automobile Association, which provides insurance to military personnel and their families) are exempt from age restrictions. Age restrictions may also be bypassed as part of a corporate contract with a rental agency, which provides the same rental rate for all employees renting under the terms of that contract (for renting a car while on a business trip).

Insurance premiums—the amount the insured pays in order to maintain his insurance policy in force—are based both on the types of coverage provided and on statistical actuarial data that bear on the probability of an insurance payout. That is, those drivers and vehicles that are statistically more likely to be involved in collisions, thefts, and other payout events are charged higher premiums. Factors impacting the premium include driver profile data including age, gender, and especially driving history, and vehicle data including the safety of the vehicle, how much it is driven, and the purposes for which it is driven. Factors that result in lower premiums are sometimes touted as discounts. For instance, drivers who can show that their insured vehicle is used for only a limited amount of driving each year may qualify, under some insurers' terms, for a discount on insurance for that vehicle.

Driving history is a major factor in determining a driver's insurance premium. The premium

will be higher if a driver's driving record includes violations such as speeding, illegal passing, and failing to abide by a stop sign, red light, or other traffic signal, as well as more serious misdemeanor- or felony-level crimes. Statistically, such violations indicate a pattern of behavior and are associated with a greater risk of accidents.

Accidents also greatly influence the amount of the premium, both directly and indirectly, in the form of removing factors such as safe driver discounts. Frequent accidents may even result in the insurer refusing to provide coverage, though more often the premium will simply be raised to a much higher level.

In most states and under most insurers, liability insurance only covers claims made against the policyholder, a driver specifically listed in the policy, or a driver of the policyholder's vehicle who is not specifically excluded by the policy and who does not live at the policyholder's address. The reason for this last requirement is to avoid skewing the liability premium by insuring vehicles used in common by members of a household under the name of the "cheapest" driver—that is, the driver whose demographic profile and driving record will lead to the lowest premiums. Given that women are typically offered lower premiums than men, and that young and inexperienced drivers are charged higher premiums than adult drivers with years of experience, this would not be a rare occurrence, and the proviso makes certain that the insurance policy of a household with teenage drivers will correctly reflect the associated risks. Because the cost of insurance is carried by every policyholder—that is, every policyholder's premiums generate the revenue the insurer needs to draw from in order to pay claims—it is in every policyholder's interest for premiums to accurately reflect risks.

Twelve states and several Canadian provinces require insurance providers to offer no-fault insurance. Kentucky, New Jersey, and Pennsylvania allow policyholders to choose between no-fault insurance and a traditional tort regime. No-fault insurance is insurance that reimburses the policyholder with no consideration of fault but places restrictions on the policyholder's right to sue other parties for damage resulting from the accident. No-fault regimes take a different view of accidents and risk than the traditional regime does, since being at fault for an accident does not increase a

driver's premiums. No-fault policies also may be seen as more practical in areas with large numbers of uninsured drivers. Florida, Michigan, New Jersey, New York, and Pennsylvania all limit the kinds of losses that can be used as the basis of a lawsuit (that is, that permit a tort), a limit that usually consists of death and permanent disability. Hawaii, Kansas, Kentucky, Massachusetts, Minnesota, North Dakota, and Utah all place a monetary limit on the damages that can be awarded (ranging from \$1,000 in Kansas to \$5,000 in Hawaii). The number of states with no-fault laws, most of which were enacted in the 1970s, used to be higher, but many states have repealed these laws.

Because many uninsured drivers never pay for the damage they cause in accidents, insured drivers pay a considerable amount of money. About one in seven drivers is uninsured (due to an increase since the 2008 financial crisis), according to the Insurance Research Council, usually because they can't afford insurance. In most cases, uninsured drivers lack sufficient assets to cover the costs of serious accidents. The most recent data on the cost of uninsured motorists comes from a 2007 study by the National Association of Insurance Commissioners, which said the cost in 2007 came to \$10.8 billion. This amount can be assumed to have increased with the increase in the number of uninsured drivers.

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See Also: Automobile Accidents and Prevention; Automobile Industry, Economics of; Automobile Safety Inspections and Registration; Driver Licensing; Traffic Laws and Enforcement.

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Automobile Manufacturing and Sales

Automobiles developed from several sources. Advances in bicycles and tricycles were coupled with engines to produce four-wheeled cars. In some cases, steam was used. The Stanley Motor Carriage Company (American) manufactured steam engine vehicles, popularly known as "Stanley Steamers," from 1902 to 1924. The light wooden frame of the car was carried on four bicycle wheels and propelled by a steam engine heated by its kerosene-fed boiler. Steam engine cars included the White Steamer (White Motor Car), the Alena Steamer (Alena Steam Products Company), Davis Steam Car, and Coats Steam Car, as well as others.

Electric cars were manufactured in Europe in the 1800s. In the late 1800s Americans began to develop electric cars. The Electric Carriage and Wagon Company of Philadelphia manufactured a fleet of taxicabs for New York City. The Woods Motor Vehicle Company of Chicago produced the 1902 Phaeton electric car, which outsold other types of cars. However, even the advances in electric battery technology, the lack of smell associated with gasoline cars, the lack of a need to shift gears, and the safety of not having to use a crank to start its engine were not enough to save the electric car from gasoline competitors after peak production in 1916.

In 1860 Etienne Lenoir built the first internal combustion engine. In the 1880s Gottlieb Daimler and Carl Benz independently developed their own internal combustion engines. In 1885 Benz built the first gasoline-powered car. Made of bicycle parts, it attained speeds of 12 miles per hour (20 kilometers/hour). Others began to manufacture "horseless carriages." The Panhard Levassor car (1891) was manufactured with many of the design principles still used in automobiles, including a front-end engine, a gearbox, foot-operated clutch, rear-wheel drive, and a radiator to cool the engine-cooling water. Others in the 1890s in Europe who built automobiles included Peugeot, Renault, Daimler, Benz, and Fiat.

In 1896 Henry Ford produced the quadricycle. Earlier in his career he had worked with Westinghouse, servicing their steam engines. At this time he was chief engineer for the Edison Illuminating Company. With Edison's encouragement, he began to manufacture gasoline-driven automobiles.

In 1899 Ford founded the Detroit Automobile Company (DAC), but because its cars were poor quality and expensive, he dissolved it in 1901 at a substantial financial loss. In 1903 he founded, with others, the Ford Motor Company. In October 1908 he introduced the Model T, with its steering wheel on the left. Simple to drive and using a manufacturing innovation, the assembly line, Ford mass-produced Model Ts at prices working people could afford. From a price of \$825 in 1908, the price fell to \$360 as production volume increased.

Using an assembly line, Ford eliminated the problems of expensive craftsman-made cars that varied in quality. Instead, every Ford car was the same with standard interchangeable parts that were assembled at a standard labor cost. In 1909 over 118,000 Model Ts were manufactured. By the 1920s a majority of Americans were able to drive the basic Model T. His combination of high efficiency and high wages were adopted by many others as “Fordism.”

The impact of an ever-increasing number of automobiles required road and bridge improvement. The traffic light, invented by Garrett Morgan of Ohio, aided the flow of traffic. In addition, service stations, parts and tires supplies, road maps, motels, and many other aids to automobile travel were created and placed in reach of the automobile market. In addition, trucks—“automobiles” for freight—were soon filling the growing road system.

Hundreds of car companies were founded and most soon folded in the early history of automobile manufacturing. The United States soon became the automobile manufacturing center of the world, a title it would hold until the 1980s when first Japan and later China would take the leads in production. By the end of the 1920s three large automobile companies dominated the industry. These were Chrysler, Ford, and General Motors (GM), which were known as the “Big Three.” General Motors made Chevrolet, Pontiac, Buick, Cadillac, and other brands. In addition, other companies such as the Hudson Motor Company (reorganized as American Motor Company in 1954), Studebaker Company, Nash Motors (Nash-Kelvinator Corporation), Crosley Motors, and the Packard Motor Car Company also contributed to the supply of automobiles available to Americans.

During the Great Depression car sales dropped dramatically. Many luxury car companies, including the Stutz Motor Car Company, Pierce-Arrow



Luxury automobiles on display at a Mercedes-Benz dealership in Munich, Germany, in 2013. Despite widespread financial crises starting in 2008, by 2010 it was estimated that there were more than a billion vehicles worldwide—double the number in 1986.

Motor Car Company, Peerless Motor Company, Cunningham, and the Marmon Motor Car Company, were forced out of business. Ford reopened for production as sales of automobiles slowly increased between 1931 and 1941 from over 1 million to over 3 million. The companies that survived the Great Depression were pressed to supply the government with vehicles during World War II. After the war ended in 1945, their assembly lines began supplying the pent-up demand for automobiles in America and around the world. From 1945 to after 1965 they dominated the global automobile market. Sales in 1950 were over 5 million out of a total 6.25 million manufactured worldwide.

Beginning in the late 1950s, foreign automobiles began to enter the U.S. market as gasoline prices were increasing. The Volkswagen Beetle became a high-selling automobile. Italian-, French-, and British-made cars also appeared on U.S. streets and highways. Yearly sales of American cars rose steadily to a peak of over 11 million in 1973 when the Arab

oil crisis seriously affected sales, which dropped to only 8 million plus vehicles. Two years later, sales again rose to over 10 million until 1980 when sales dropped again.

Sales of US cars and trucks generally had been handled by either a private dealership that held a franchise to sell the automaker's vehicles or a dealership that was a subsidiary owned by the automaker company. Often the dealers contracted with the automakers to sell their vehicles. The dealerships provided not only vehicles to buyers but also service for maintenance and repairs.

Financing automobile dealerships requires significant sums of money for the physical location of the dealership, its employees, its service department, and its inventory of new cars and trucks. Different ways of financing dealership operations have been used over the years, ranging from the automaker supplying funds, the dealer using the franchise's funds, or the dealer using loans supplied by outside investors. Inventory is often used as security for the loan.

After the cost of purchasing a home, an automobile is usually the second-largest purchase for most consumers. Some people are able to pay cash to buy a new or used car or truck. Others have to borrow in order to buy the vehicle. Many buyers can borrow directly from a finance company, bank, credit union, or other lending institution. Most dealerships have their own loan department where "dealership financing" may be arranged. The buyer and the dealer agree to the terms of the sale plus the interest cost of the loan. This system is convenient and has worked well for decades. Once the deal is made, the dealer may keep the loan and collect the monthly payments of principal and interest, but it is common for the loan to be sold to a finance company.

The latter part of the 1970s were years of significant inflation. Increasing costs and inattention to quality in favor of quantity of production caused many Americans to feel that their complaints were not being heard by the Big Three and their "rattletraps" produced with little care for consistent quality. Disenchanted with American automakers, consumers turned to Japanese-manufactured cars made by Toyota, Honda, Mazda, Isuzu, and others. Following the virtually complete destruction of their industry in World War II, the Japanese rebuilt it with careful attention to quality control. Influenced by American quality control experts, such as

W. Edwards Deming, Joseph Juran and others who were largely ignored in the United States, the Japanese produced high-quality reliable cars that were reasonably priced.

In 1947 Deming, a very skilled statistician, left the Bureau of the Census to begin working for the Supreme Command for the Allied Powers in order to prepare for the 1951 Japanese census. By 1951 he had met many important Japanese leaders and was becoming versed in Japanese culture. Among those he met were Lord Kaoru Ishikawa (who developed the Ishikawa, or Fishbone, Diagram) and a group composed of the presidents of Japan's leading industries. They soon adopted the philosophy of quality as a permanent feature of Japanese production. In 1980 the American automotive industry and other American manufacturers discovered Deming and the quality control philosophy. The discovery came when NBC broadcast a television documentary program, "If Japan Can ...Why Can't We?" The Total Quality Management (TQM) movement was launched soon thereafter. The new slogan at Ford Motor Company became "Quality Is Job 1." Japanese innovation was greater than manufacturing efficiencies. Daihatsu attracted new car buyers with its lifetime extended warranty program. Korean automobile makers also entered the U.S. market and began to make themselves major challengers to American car manufacturers.

American union contracts from 1937 onward made U.S. manufacturing costs greater than those of many foreign manufacturers. A combination of high oil prices and increasing foreign competition seriously affected American automobile companies. While they were able to recover some during the 1990s and into the mid-2000s, the financial crisis of 2008 severely impacted the Big Three. Ford continued to operate, but GM and Chrysler filed for bankruptcy in order to reorganize. Reducing the cost of labor contracts was part of the reorganization and recovery. The companies that emerged were downsized, and some cars, such as the Oldsmobile, met their end.

American car sales had risen again in the later 1980s to over 10 million units and thereafter remained steady at around 8 million units per year. From 1980 until 2012, U.S. car manufacturing declined from being the dominant global producer to a smaller global market share. China is now the world's leading car manufacturer, the United States

is second, and Japan is third; European, Brazilian, and Indian sales compose significant portions of total sales.

Automobiles continue to be driven in ever-increasing numbers around the world. It was estimated in 2010 that the world number of automobiles was over a billion vehicles. This was double the number of vehicles in 1986. Much of the increase represents automobiles manufactured in China and India. Hybrid gasoline-electrical cars such as the Toyota Prius are selling well, while newer biofuel, hydrogen-powered, and electric cars are being developed.

By the end of 2013 China was quietly buying real estate in order to open Chinese automobile manufacturing facilities in Detroit. With real estate cheap and with an abundance of unemployed skilled automobile workers and engineers in the area, the investment opportunities looked very good. The Chinese and other foreign investors in the U.S. automobile industry were aided by the financial troubles of the Big Three.

The financial crisis of 2008 adversely affected the Big Three automobile companies in Detroit. Historically, money had been borrowed in order to finance automobile manufacture and sales. However, the money was suddenly unavailable so, in order to avoid bankruptcy, they turned to the federal government. They were able to secure \$50 billion in guaranteed loans as a bailout. Critics denounced the move, but supporters of the loans said that three million or more workers would be unemployed in a short time if the bailout loans were not made.

The Barack Obama administration, which took office in January 2009, used \$24.9 billion from the Troubled Asset Relief Program (TARP) to create the Automotive Finance Program to make loans to the automakers so that they could lend to car buyers. In order to get the bailout, the automobile companies agreed to consolidate operations and also to move toward the rapid development of energy-efficient trucks and cars. Also included in the bailout terms were delays in contributing to the health insurance and retirement benefits of both retirees and current workers. Ford Motor Company did not need the loans; however, it took the bailout money in order to stay competitive. By 2013 all of the automobile bailout loans had been repaid with interest.

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See Also: Automobile Culture; Automobile Industry, Economics of; Automobiles, Passenger.

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Automobile Operating Costs

Automobile operation involves both direct and indirect, internal and external costs. Direct costs include (depreciated) vehicle purchase or leasing costs, insurance, registration, fuel, maintenance, parking, tolls, and costs associated with time lost from congestion and personal or property damage from crashes. Indirect costs are much less apparent to drivers but can represent 30 percent or more of total vehicle operating (plus ownership) costs. They include external accident costs (such as government-paid medical costs, police response costs, and the lost economic activity of those delayed by accidents), local road construction and maintenance costs, employer-paid or tax-supported parking, air pollution damages, road noise, congestion costs, greenhouse gas emissions, water pollution, and others. Direct costs are those borne by the travelers themselves or those who provide the vehicles, fuel, and roadways, while indirect costs are borne by others, who do not make the decision to manufacture or use the vehicle imposing the costs. Many

of these costs (even the relatively direct costs) are hidden from drivers when they decide whether or not to use their automobiles for a trip.

Americans spend nearly 20 percent of their household budgets on vehicle expenses, including 9 percent on vehicle purchases, 3 percent on gasoline and motor oil, 1 percent to finance the vehicle, over 2 percent on insurance, and nearly 3 percent on maintenance, repairs, and other charges. For the average U.S. household in 2002, these costs made up \$7,371 on average.

Depreciation makes up nearly half the costs of new-vehicle ownership, over the first five years. Fuel costs make up 24 percent, followed by interest payments at 11 percent, insurance at 10 percent, and maintenance, repair, and taxes at about 8 percent. Vehicle depreciation depends on vehicle usage; the more a vehicle is driven, the less it is worth. Using the Kelly Blue Book to compare resale values of sedans, Todd Litman (2010) suggests that every passenger vehicle-mile traveled costs 18 cents in value depreciation. The American Automobile Association (AAA) suggests that the average new sedan loses value at a rate of 24 cents per mile. Depreciation depends largely on how well a vehicle holds its value, which is specific to both the vehicle make and model, so a large range of depreciation values should be expected.

Automobiles also require routine maintenance due to vehicle wear and tear, parts replacement, and associated labor costs. For example, oil changes are common around every 5,000 to 7,000 miles and tire replacements every 20,000 miles or so, depending on driving behavior and maintenance. Administrative costs also come with owning a vehicle. Drivers usually pay a fee for vehicle license and registration, along with vehicle purchase taxes. The AAA notes that many vehicle owners also pay finance charges for loans and leases. It computes a number of ownership costs for the average car, as shown in Table 1.

Fuel prices have impacted the amount that people drive, as well as vehicle ownership levels. The U.S. fuel price is typically much lower than prices in many European countries, while oil-rich states like Saudi Arabia and Venezuela enjoy very low prices (on the order of cents per gallon). Though diesel-powered vehicles enjoy higher fuel economy (thanks to a higher compression ratio), diesel fuel is typically priced higher than gasoline, due to a high

Table 1 Average new sedan ownership and use costs

Fuel costs	14.45 cents/mile
Maintenance costs	4.97 cents/mile
Tires	1.00 cent/mile
Full-coverage insurance	\$1,029/year
License, registration, taxes	\$611/year
Depreciation	\$3,571/year (when driving 15,000 miles/year)
Finance charges	\$848/year

Source: American Automobile Association. "Your Driving Costs." <http://newsroom.aaa.com/wp-content/uploads/2013/04/YourDrivingCosts2013.pdf> (Accessed July 2013).

global demand for diesel, the cost of transitioning to lower sulfur diesel fuels, and excise taxes that may be higher than those on gasoline.

Parking costs vary by location and parking structure. Litman estimates that annual on-street parking costs for a single parking space can vary from around \$500 in a suburban location to as much as \$2,500 in a central business district (CBD). This cost includes discounted land purchase, construction, and operation and maintenance costs. Annual garage costs (to the vehicle owner) may range from \$1,900 per space in a suburban location to \$3,800 per space in a CBD. The 2008 average annual (unreserved) parking cost in the United States was around \$1,500. Some of the highest (unreserved) average parking costs in the nation are found in New York City and Boston, Massachusetts, at \$5,772 and \$5,220 per year, respectively.

Automobile owners in urban and suburban areas may have to pay for parking spaces at home, at work, or when they make other trips, for example, for shopping, entertainment, and recreation. Parking costs may be paid on an annual, contractual basis or may be variable and charged at the time of each trip, through a meter, fare box, electric pay space, attendant, or valet. Hourly parking rates vary by region and garage and usually depend on supply versus demand. For instance, the average rate for small urban CBDs may be \$1 per hour of parking, versus \$1.50 per hour in larger CBDs. Free parking spaces are common in suburban and rural areas, in the form of large parking lots. Parking costs and

Table 2 USDOT recommended costs of emissions

Emission Type	Dollars/Ton
VOCs	\$1,700
NO _x	\$4,000
SO ₂	\$16,000
PM _{2.5}	\$168,000
CO ₂	\$5–\$136

Source: U.S. Department of Transportation, 2011. "Benefit-Cost Analysis (Bca) Resource Guide." <http://www.dot.gov/sites/dot.dev/files/docs/USDOT%20BCA%20Guidance.pdf> (Accessed January 2014).

parking availability have significant implications on mode choice and vehicle miles traveled.

Indirect and Hidden Costs

In addition to the direct costs of parking, fuel, tolls, and others, there are many indirect costs, such as travel time, which could be spent on other activities (such as earning income at work or enjoying leisure time). Individual value of travel time (VOTT) varies based on how much an individual might otherwise be earning or even a general aversion to driving in general or being stuck in traffic. The U.S. Department of Transportation (USDOT) has recommended hourly values of travel time (in 2000 U.S. dollars) of \$10.60 to \$21.20 per person-hour for local surface modes of travel, \$14.80 to \$21.20 for intercity travel, and \$18.80 for truck driver travel, both local and long distance. VOTT also further varies by trip purpose and circumstance. For instance, if one is late to an important meeting or rushing to catch a flight, VOTTs can run very high, even for the low-income traveler.

Other "hidden" costs to travelers may include external costs imposed on society and the environment. These costs include the impacts that owning and operating an automobile have on others, by reducing available space on roadways and in parking lots, increasing the chance of crashes (by more potential conflict opportunities), and degrading the natural environment. Litman suggests that increased crash rates add about 10 cents per mile, and congestion and environmental costs contribute an additional 4 cents per mile. Roadway land value, fuel externalities, and traffic services contribute another 1 to 2.5 cents per mile. The implicit,

and often subjective, costs of long-term land use changes and equity impacts, due to automobile reliance, are certainly important but are much more difficult to estimate.

Emissions impacts are an external cost that is often estimated, though specific values are subjective and sometimes contentious. Carbon dioxide (CO₂) emissions are especially difficult to quantify, since impacts related to climate change add an additional but highly debated cost. Table 2 shows the USDOT (2011) guidance for estimating pollutant emission costs by type.

Some other external costs that are difficult to quantify are the stress and health impacts of driving in congestion for long periods of time. The physical response to traffic is well documented as a pervasive medical concern, but valuing these irritations is challenging. Time spent in congestion, however, can be evaluated by considering the lost time due to traffic delays (relative to free-flow conditions, for example). The Texas Transportation Institute's Urban Mobility Report estimates that congestion costs Americans \$121 billion a year in lost productivity, including wasted fuel costs and wasted time for trucks moving goods.

Alternatives

An alternative to owning or leasing a vehicle is renting, borrowing, or sharing a ride (carpooling). There are many car sharing organizations around the world that allow members to rent vehicles on a per-minute, hourly, daily, or weekly basis. Car sharing is popular in Europe, especially in Switzerland, and companies like Daimler's Car2Go and ZipCar have been expanding rapidly in North America. Car2Go charges users a one-time membership fee and a per-minute rate of 38 cents (as of 2013 in the United States) to use a two-seater Smart car. This fee includes fuel, maintenance, insurance, and any other fees: users pay only the per-minute rate. ZipCar provides more vehicle choices (such as sedans, trucks, and SUVs) and charges an hourly rate, with initial and monthly membership fees. Such programs provide travel flexibility, facilitating occasional vehicle access, alongside other modes. However, those needing daily, frequent vehicle access typically find car sharing costs uncompetitive.

Driving an automobile involves a significant number of costs, many of which are paid indirectly

or borne by society, rather than by individual drivers. Direct costs vary by vehicle, driving behavior, and location; indirect costs require subjective and variable valuation of safety, pollution, and time/cost impacts. Even as vehicle and infrastructure efficiency and pollution control systems have improved, driving produces externalities that regularly diminish quality of life and the natural environment.

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See Also: Automobile Culture; Automobile Financing; Automobile Trips; Automobiles, Passenger; Car Sharing; Environmental Impacts.

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Automobile Safety Inspections and Registration

Automobile accidents by 2012 had claimed the lives of at least 3,572,832 people since the first fatalities in the late 1890s. In order to reduce the number of accident fatalities, highway injuries, and property damage, automobile safety studies were developed. These deal with automobile designs, their construction, equipment, and the development of regulations to minimize highway deaths.

Road traffic safety focuses on roadway design. This area of study seeks methods and measures that protect people and vehicles on the nation's roadways from being injured or killed. It includes studies of all users of the roads: pedestrians, cyclists, motorists, and passengers—including passengers in commercial or other forms of public transportation. The best practices developed to date focus on prevention despite human errors of drivers. In older studies it was assumed that drivers were complying with traffic regulations when often they were speeding or were distracted. The goal of safe road design is to create road environments that will prevent accidents at normal vehicle speeds.

The approach of road traffic safety is to develop a safe system that will prevent death or serious injury in the event of an accident. This is done by keeping the impact energies below the levels that are likely to cause death or serious injury. Prior to the 1970s, automobile frames and bodies were solid. The effect of a head-on crash at 55 miles per hour was likely to be so horrific that drivers and

passengers were not likely to walk away unscathed. Since that time, cars have been built to displace the energies of a crash. The car is usually a total loss, but the driver and passengers are often able to escape without serious injuries.

A major study of automobile safety was issued by the Cornell Aeronautical Labs of Buffalo, New York. It concluded that seat belts and padded dashboards were crucial to preventing injury.

Vehicle accidents are costly to employers when accidents are work related. The costs are due to loss of productivity and to property damage. The toll to humans is often incalculable. Fatal crashes for truck drivers are of higher frequency than in other occupations. Also, many companies own vehicles driven by employees for deliveries, sales, repairs, calls, client visits, and many other reasons. Young drivers are very vulnerable. Nearly half of the fatal injuries experienced by drivers 18 and younger were work related.

A major problem is the number of pedestrians who are killed by automobiles. The impact of being hit by an automobile is much greater for the pedestrian than for automobile occupants. Currently, in the United States pedestrians are injured by automobiles every eight minutes on average. In addition, the odds of the pedestrian being killed are much greater than for the automobile occupants. Nearly 66 percent of people killed in traffic accidents have been pedestrians.

Since the 1970s, improvements in highway design and construction, along with automobile designs, have contributed to declining injury and death rates in first world countries. However, as automobile and other motorized vehicle traffic has increased dramatically in China, India, and in areas of the third world, accidents have increased.

Studies have used the Peltzman effect, which is also known as risk homeostasis or risk compensation. The effect of risk compensation is observed when people adjust their behavior in response to a risk they can tolerate. This means that people behave more cautiously if they feel a higher level of risk and are less guarded if they feel more protected. The theory is a product of road safety research. Studies of a variety of safety interventions did not produce the reductions in risky behaviors nor have the levels of benefits.

Examples of the risk compensation effect were seen in the increases in risky driving behaviors that

occurred with the introduction of seat belts and bicycle helmets. Other increases were observed in drivers who tailgated following the introduction of antilock brakes. In the politics of automobile safety, arguments have been made against the use of safety devices or other safety measures, using risk compensation theory to claim the drivers will just engage in more risky behaviors because they feel safer.

To reduce the effects of risk compensation, which resemble those of moral hazard in economic theory, the concept of shared space is being added to new road designs. The new approach increases the levels of uncertainty for drivers and other road users by removing traditional road markers. The effect is to increase the uncertainty felt by drivers so they slow down. Experiments have demonstrated that shared space can be effective in reducing traffic accidents.

Inspecting vehicles for safety in the United States is regulated by the separate states. Some states have annual inspection requirements. A few have biennial inspection requirements. Other states require safety inspection upon the arrival of a vehicle in the state. Others, such as Georgia and New Jersey, do not have any inspection program. Most states have some kind of automobile emissions inspection if the air quality of the state or a city, such as Atlanta, warrants inspections. Most states have a commercial vehicle inspection program.

In states where a vehicle safety inspection program is enforced, the vehicle is issued an inspection decal to affix to the car windshield or perhaps the rear window. In the case of motorcycles, trailers, and similar vehicles, the sticker is attached permanently to the body of the vehicle. The inspection sticker or decal signifies that the vehicle has passed inspection. It also displays its expiration date. In some states the owner of a vehicle must present proof that the vehicle has passed the safety inspection before the vehicle can receive a license plate ("car tag"), just as proof of insurance is required in some jurisdictions before the license plate can be issued.

In some states the levels of fraud in the inspection programs challenged the efficacy of the inspections. The lack of popular support undermined the effectiveness of the program of safety inspections. Many whose automobiles were new and safe saw the requirement as a waste of time and money. Controversies have arisen at times

over whether safety inspections are cost-effective ways to increase highway safety.

Vehicle registration is usually a government mandate. The goal is to establish a clear title of ownership and then, in most cases, to impose a tax. Titles are one way of combating car thieves, who find it much easier to sell stolen vehicles that cannot be traced easily. The length of time that registration is valid varies among states. Some states require annual reregistration.

A vehicle registration tax may be a nominal fee or an ad valorem tax or some other kind of tax, such as a sales tax on the purchase price of the car. Most jurisdictions require motor vehicles to have a vehicle registration plate that is permanently mounted in a visible place near the engine. In addition, the owner of the vehicle is issued a vehicle registration certificate. In some jurisdictions the car license plate belongs to the owner and not to the automobile. Therefore, when a car is sold, the new owner must obtain a new license plate for the car. In other jurisdictions the car tag belongs to the automobile and is transferred along with the registration at the time of the sale of the car.

In the United States vehicle title registration varies from state to state. In most states the registration is handled by the state's division (or department) of motor vehicles (DMV). In a few states the DMV has another name or registration is conducted by another state agency. In order to legally use a passenger or commercial vehicle on public roads a vehicle must be registered. Vehicles not used on public roads, such as farm equipment or even vehicles used in mines or on private land such as farms, may not be subject to registration.

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See Also: Automobile Accidents and Prevention; Automobile Emissions Controls; Automobile Insurance; Automobile Safety Systems; Driver Licensing; Motorcycle Safety; Passenger Van Safety; Pedestrian Safety; Sport Utility Vehicles; Truck Inspections and Vehicle Licensing.

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Automobile Safety Systems

Automobile safety systems have come a long way since Congress passed the first automobile safety standard law in 1959. Today safety is part of the mandatory annual automobile inspection in most states, and manufacturers offer safety features far beyond what is required, either as standard equipment or as an option. Most safety features are aimed at preserving the safety of the driver and passengers; pedestrians remain far more likely to be killed in vehicle crashes, though collision prevention features help somewhat with this. There are, broadly, two types of safety features. Active safety features work to help prevent crashes from occurring. Passive safety features help reduce the injuries and fatalities that result from the crashes that do occur.

Active Safety

Active safety features include such basic features as the car's steering and suspension systems and

brakes, which give the driver control over the vehicle's motion to respond to events; the headlights, signal lights, and reflectors, which help make the car visible to other drivers; and the mirrors, which give the driver a greater awareness of his surroundings. Beyond these basics, there are many more active safety features included in many modern vehicles.

Backup cameras have become increasingly popular, as they provide a dashboard display from a rear-facing camera to assist the driver with backing without needing to swivel back and forth. This may be offered in combination with backup sensors, which sound an alert when the backing vehicle comes into close proximity to an object in its path. Other warning systems alert the driver if the car is too close to the vehicle ahead or has begun to drift out of its lane (which may indicate a driver who is nodding off at the wheel), or let the driver know of changes to the car's condition, such as low fuel, low tire pressure, an overheated engine, or other problems. The driver's ability to respond may also be assisted through infrared night vision systems or adaptive headlights that increase visibility without impairing the vision of oncoming drivers.

Modern cars also possess systems that help prevent loss of control and collisions, such as improved cruise control systems that respond to the proximity of the vehicle ahead of the driver and adjust speed to maintain a safe distance, traction control systems that respond when wheels begin to spin, and electronic stability control systems.

Electronic stability control systems, which some manufacturers call dynamic stability control systems, active handling, vehicle stability assist, or StabiliTrak, were developed at the end of the 20th century and work to ensure steering control by individually braking the wheels as necessary when steering control loss is detected. The system monitors the steering wheel angle to determine the driver's intended direction and compares it to the vehicle's actual direction, derived from observations of the vehicle's rotation, lateral acceleration, and the speed of each wheel. The method by which the system corrects the vehicle's direction is essentially weather independent. While traction control systems help with the loss of control that results from spinning wheels in icy, muddy, or wet conditions, the key scenario in which electronic stability control is needed is when the driver must suddenly



A dashboard display for the adaptive cruise control system in a Volkswagen Golf. Advanced cruise control systems like this can now respond to the proximity of the vehicle ahead and adjust speed to maintain a safe distance.

swerve, such as to avoid a pedestrian or another vehicle. In these situations, stability control assists to keep the driver from losing control of the vehicle. In some vehicles, electronic stability control and traction control are combined. A National Highway Traffic Safety Administration study found that electronic stability control reduces crashes by 35 percent—and by 67 percent for sport utility vehicles (SUVs).

Braking enhancements include antilock brakes, which prevent skidding by preventing the wheels from locking up during braking. Antilock brakes were one of the first major braking enhancements to be adopted, and were originally developed for aircraft. They have been further enhanced with the addition of emergency brake assist technology, which determines the presence of an emergency based on the speed and force with which the driver pushes the brake pedal and in response to an emergency applies the brakes fully. This helps ensure a full braking, even if the driver is startled by the kinetic feedback of fully depressing the pedal. BMW further expanded its antilock braking system with cornering brake control, which applies braking

pressure asymmetrically while cornering, which also helps with stability. Similarly, many manufacturers use electronic brakeforce distribution, which varies the amount of force on each brake based on detected conditions. This helps avoid skids that result from abrupt braking.

Passive Safety

Passive safety features reduce the severity of crashes. For instance, automobiles are designed with a crumple zone that, in the event of a collision, transfers the energy of the crash away from the passengers by controlling the deformation of the vehicle. This is why the body of an automobile may be greatly mangled by an accident in which there are no or only minor injuries. Crumple zones are usually positioned toward the front in order to absorb the impact of head-on collisions, where most impact damage occurs, but rear and even side crumple zones are sometimes found.

The basic function of the crumple zone is to transfer crash energy along the outer elements of the vehicle rather than passing into the cabin (the interior) and causing injuries as passengers are hurt by broken or deformed interior elements. In conjunction with the crumple zone, automobiles are often designed with anti-intrusion bars, which limit the effect of side impacts on the cabin, and with stronger and more resilient materials at the parts of the cabin that experience the greatest forces in collisions. The goal is not only to limit the impact of collisions on passengers but to prevent the cabin from deforming in a way that makes it difficult for passengers to escape the vehicle (or be removed from it by emergency personnel) after a crash.

Seat belts and air bags are the best-known passive safety features. The modern design of the seat belt has gone through many changes, since early studies determined that while seat belts may have prevented one class of injury, they were frequently causing other injuries in collisions. Today's seat belts include a shoulder strap, which prevents the likelihood of the head snapping forward (though shoulder strap usage is not mandated in as many states as seat belt use is).

Air bags may be placed driver-side, passenger-side, or both, and consist of flexible cushions that rapidly inflate in the event of a collision, softening the impact of the passenger against the steering wheel or dashboard. Though designed in the

early 1950s, they were not introduced in the United States until the 1970s; they became popular features in the following decade as American interest in automobile safety increased. Many car models now come equipped with multiple air bags to protect passengers in the case of front, side, or even rear-end collisions.

Windshields and windows are also manufactured to minimize their contribution to injuries in the event of a collision. Windshields are designed to be shatterproof through the application of laminate materials, such that the windshield will crack but will not break into pieces. Side and rear windows are designed to break into small blunt pieces that cause minimal injury.

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See Also: Automobile Accident Avoidance Systems; Automobile Accidents and Prevention; Automobile Design; Automobile Driver Warning Systems; Automobile Engines; Automobile Safety Inspections and Registration.

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Automobile Tires, Nitrogen Inflation and

The use of nitrogen instead of air to inflate automobile tires may provide benefits in the areas of fuel efficiency, maintenance, and safety. Though not widely available to the average consumer in the past, nitrogen tire inflation has been used for

many years in performance settings such as Formula One and NASCAR racing vehicles and Tour de France bicycles. Nitrogen gas also has been used to inflate tires for some off-road heavy equipment and for both commercial and military aircraft. The National Aeronautics and Space Administration (NASA) used nitrogen-filled tires for its lunar roving vehicle. The main reason nitrogen is not yet the inflation gas of choice for consumer car and truck tires is that for many years there had not been a cost-effective way to obtain it.

Some manufacturers found a way to tap the potential of nitrogen gas in the consumer market using cost-effective membrane technology systems for extracting pure nitrogen from compressed air. The systems can be used with existing compressed air systems at dealerships and gas stations, keeping costs low and making nitrogen available via the same delivery network as oxygen inflation.

Benefits of Nitrogen

With conventional air-filled tires, tiny oxygen molecules leak out through the permeable rubber tire walls at a rate of approximately 1.5 pounds per square inch (psi). This causes tires to be underinflated in as little as one month if not checked regularly. The process also oxidizes and weakens the tire's steel belt structure and facilitates moisture and contaminants that further shorten the life cycle of the tire.

Nitrogen molecules are larger than oxygen molecules and take as much as six times longer to reach the same level of leakage and underinflation. Nitrogen gas also is very clean and does not hold moisture. Keeping moisture out of tires significantly reduces the likelihood of valve corrosion, tread separation, belt failure, and other causes that can lead to tire blowouts. Nitrogen is noncombustible as well, and tires filled with nitrogen do not heat up and expand, which improves overall tire performance. Moreover, because it is a naturally occurring inert gas—accounting for 79 percent of the air humans breathe—nitrogen is environmentally safe and has a shelf life of more than 20 years if appropriately maintained.

The use of nitrogen in tires also helps protect the environment and generate savings by providing better ability to retread worn tires. Retreading makes an old tire serviceable again by removing and replacing worn and damaged rubber belts, or treads.

In this way retreading extends the useful life of the worn tires and decreases the production need for completely new tires, which saves millions of gallons of oil each year and reduces use of finite rubber resources and loss of natural habitat. Keeping tires longer also lessens the volume of solid waste from trashed tires in need of disposal. Retreading also lowers costs for companies and consumers because retreading is less expensive than purchasing and installing new tires. For many commercial vehicle fleet businesses, tire replacement is the third-largest line item in the operating budget. By increasing the use of retreading, companies can generate significant cost savings for the bottom line.

Proper Tire Inflation

A number of service equipment manufacturers developed on-site nitrogen generator systems that utilize a selective permeation approach to separate oxygen and moisture from a site's existing compressed air lines in order to capture nitrogen. The key feature of such systems is a membrane that separates the gases, allowing oxygen and water vapor to be removed, leaving essentially pure nitrogen that is stored separately until it is needed to inflate tires.

The generators, which are typically set to deliver the recommended 145 psi of pressure required for optimal nitrogen tire inflation, are generally anchored to the shop floor and connected to the existing air system's inlet valve. No other equipment is needed for operation except a hose to inflate the tires. The systems are maintained through regular nitrogen calibration and replacement of filters and gas analyzers.

Tires that contain both air and nitrogen should be emptied and then reinflated with the appropriate volume of nitrogen to ensure safe and effective operation. In cases where a mixture of both oxygen and nitrogen inflation are utilized—when nitrogen inflation is not available, for example—it is best to match the combined mixture in all tires. In other words, if a nitrogen-inflated steering tire has been repaired and refilled with air, it is recommended that nitrogen be let out of the other steering tire and refilled with a similar amount of air until both tires can be purged and reinflated with full nitrogen pressure.

It is still important for drivers to check tire pressure regularly, regardless of which inflation method is used. The National Highway Traffic Safety

Administration (NHTSA) estimates that more than 27 percent of vehicles on the road drive on significantly underinflated tires. Tires that are underinflated are more likely to prematurely fail, leading to potential blowouts, incidents, and accidents. In underinflated oxygen-filled tires, the rubber flexes more than it is supposed to when the tire rolls. The flexing leads to distortion that generates heat, which in turn accelerates tire wear and additional pressure loss. The cycle is worse in hot weather. For every temperature change of 10 degrees Fahrenheit, there is a corresponding loss of 1 psi in tire pressure. Nitrogen-filled tires are less prone to chemical reaction and temperature fluctuations. As a result, pressure remains more constant over time. This helps preserve proper tire inflation longer and reduce chemically induced aging of tires. Reduced corrosion helps tires maintain their original properties longer and provides increased tire integrity.

Properly inflated tires not only reduce the chances of a tire blowout but also help ensure that appropriate tire contact is maintained with the road. Proper tire-to-road contact improves the vehicle's handling, enabling drivers to react more quickly and smoothly when dealing with potentially dangerous road conditions and situations. According to the NHTSA, correct tire inflation could help save as many as 50 to 80 lives per year and prevent anywhere from 6,600 to 10,600 injuries annually.

Properly inflated tires provide less rolling resistance as well, which helps increase overall fuel economy. The more stable tire pressure provided by nitrogen inflation also optimizes tire function, which can improve fuel mileage by as much as 6 percent. Coupled with less wear and tear on tires in general, nitrogen inflation offers potentially significant cost savings due to better fuel mileage and reduced maintenance and replacement requirements.

Recognizing the safety, efficiency, sustainability, and cost benefits of nitrogen gas inflation, powerhouse retailer Walmart included in its 2011 sustainability program a requirement for nitrogen-filled tires across its entire North American fleet.

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See Also: Automobile Accidents and Prevention; Automobile Design; Automobile Operating Costs; Environmental Impacts; National Highway Traffic

Safety Administration; Truck Inspections and Vehicle Licensing.

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Automobile Travel Patterns

Every eight years, the Federal Highway Administration (FHA), in the U.S. Department of Transportation, administers a comprehensive national survey of travel patterns and behavior called the National Household Travel Survey (NHTS). The most recent survey is the 2009 NHTS (conducted from April 2008 to April 2009), which was preceded by the 2001 NHTS and five predecessor surveys, the Nationwide Personal Transportation Survey (NPTS), from 1969 to 1995. Every area of the country is surveyed in an attempt to quantify travel behavior and discover changes in travel behavior over time, while analyzing the relationship between travel behavior and demographics. Data collected concern mode of transportation, distance, duration, and purpose, as well as demographic, economic, and geographic information about travelers.

Information is made available to the public as well as to urban planners, state departments of transportation, and transit agencies, in an effort to better meet travel needs and plan transportation policies. The 2009 NHTS was also the first to collect information on hybrid and alternate fuel vehicle usage and ownership, the delivery of purchases made online (and the effect on driving for errands and shopping). It also asked more granular

questions about employment-related travel, including questions about work-related travel for self-employed individuals.

Vehicles included in the NHTS include all privately owned passenger vehicles, including cars, pickups, vans, SUVs, and motorcycles. The survey did not include rental cars or taxis, cars that are part of a corporate or government fleet, or farm vehicles like tractors. The earliest NPTS did not count pickup trucks, which were primarily used as work vehicles at the time. The 2009 NHTS found 212 million licensed drivers (roughly equally divided by gender, which had been true since 1990), a steady and expected increase over previous surveys, driving 210 million household vehicles. As had been seen in the previous four decades, the growth in number of both workers and drivers outpaced that of households or persons, though the growth in the number of those driving to work slowed down at a point coinciding with the beginnings of the global financial crisis. Growth in the number of vehicles outpaced all other indicators, though the number of vehicles per licensed driver fell slightly to 0.99 (from a peak of 1.06 in 2001). About 233 billion trips were made in the survey period, for 3,732,791,000,000 person miles of travel.

Most trips surveyed by the NHTS were conducted by privately owned automobile. In 2009, the average household experienced 3,466 person-trips, of which 2,892 (83.4 percent) were by private automobile, 362 (10.2 percent) were conducted by walking, 66 (1.9 percent) by public transit, and the remainder conducted by various other means (e.g., a bicycle). In general, wealthier families conducted more trips: 4,815 among those with a household income greater than \$80,000, for instance, compared to 2,100 among those with a household income below \$10,000. Vehicle trips were very fairly evenly distributed between trips to work (22.1 percent), for shopping (22.6 percent), for family purposes, (24.2 percent) and for social and recreational reasons (21.1 percent).

The NHTS found an average of 3.02 vehicle trips per driver per day, for 28.97 vehicle miles of travel daily. This was a slight decrease in mileage from the previous two surveys (from 32.7 in 2001 and 32.14 in 1995) and a decrease in number of trips from the previous three surveys (from 3.35 in 2001, 3.57 in 1995, and 3.26 in 1990). The average vehicle trip length was 9.72 miles, a slight decrease from

2001 (9.87 miles) but longer than for all other previous surveys. Despite the decline in the number of miles traveled per household, the proportion of household trip mileage by automobile over other means of travel has stayed largely the same since 1990. Driving accounted for 88.4 percent of daily trip miles made in 2009, 88.2 percent in 2001, 91.2 percent in 1995, and 88.4 percent in 1990.

Interestingly, the decrease in trips and vehicle miles traveled (VMT) was seen in nearly all categories. The average number of trips to and from work fell from 479 a year to 457 (553 in 1995), social and recreational trips from 441 to 436, and “other” trips from 537 to 500. The number of shopping trips grew slightly, from 459 to 468 VMT. Annual work-related vehicle miles fell from 5,724 in 2001 (and 6,492 in 1995) to 5,513 in 2009; of shopping-related VMT from 3,062 in 2001 to 2,979 (despite the slight increase in number of trips); of social and recreational VMT from 5,186 to 4,842; and of “other” VMT from 3,956 to 3,515.

Commutes remained the longest trips, with an average length of 12.2 miles, a steady increase from all previous surveys. For non-work-related trips, the lowest income households were the only income group for which the number remained the same. Travel in general is strongly correlated to income, though increases in non-work-related travel level off at the highest income brackets. Men across income brackets make more work-related trips; women make more family- or shopping-related trips, reflecting the tendency of mothers and wives to take responsibility for a disproportionate share of household and child-related errands. In both cases the difference is about the same, with one gender performing about 25 percent more trips in that category than the other. Nearly half of trips by women were for personal or family errands, including shopping and transporting children to school or other destinations. Trips for school, church, and recreation remained gender equal, within the margin of error.

A key finding of the 2009 NHTS was the number of automobile trips covering distances that could have been traversed on foot or by bicycle. Sixty percent of all trips of less than 1 mile were traversed by automobile, for instance. Although the distance would be easily traversed without using a car, other conditions may have discouraged this. Even apart from traveler preference and behavior, bicycle

and pedestrian traffic is frequently discouraged by incomplete streets.

When people live in neighborhoods that lack adequate sidewalk coverage, bike lanes or paths, and safe places to cross the street, they are much less likely to use nonautomobile forms of travel. This reluctance is exacerbated in snowy regions, not only because of the discomfort of the weather itself, but because plowing of streets may create snowbanks that interfere with bike lanes, sidewalks, or crosswalks. For example, failing to shovel a path from the street portion of the crosswalk to the sidewalk presents a serious impediment to pedestrian travel.

As a general rule of thumb there is a correlation between high walkability and decreased automobile use. This has been confirmed again and again by municipal governments seeking to increase bicycle use or pedestrian travel; in communities that succeed, use of automobiles has decreased for short trips, and in some cases automobile ownership per capita has decreased overall.

In studies of time spent in a vehicle, whether as passenger or driver, only those 65 and older and 18 or younger spent less than an average of an hour a day in a car. In contrast, people between 35 and 54 years of age, the group with the largest number of employed parents of minor children, spent the most time in their cars—about 73 minutes a day, down from more than 80 minutes in 2001. Persons 55–64 years old spent nearly as long, about 69 minutes, and those aged 19–24 spent about 62 minutes a day in a car.

Interestingly, average time spent driving did not vary widely by size of city of residence. The average driving time of all drivers in the 2009 survey was 56.09 minutes, for instance. Grouped according to city size, the low was 54.79 minutes (250,000–499,999 people) and the highest was 56.85 minutes (3 million or more). This may reflect traffic congestion more than vehicle use or length of trips: commuting speed did vary somewhat by size of location, with the largest cities reporting the slowest commute speeds, at less than 25 miles per hour, while smaller cities and towns reported speeds about 27 miles per hour. All locations reported slower speeds than in the past and had experienced peak commuting speeds (around 30 miles per hour or just over) in either 1990 or 1995. Largely because of commuting, drivers took more trips per day on weekdays than on weekend days.

Overall, average vehicle occupancy was 1.67 persons per vehicle, marginally higher than in previous surveys. Occupancy rose slightly in 2009 for social and recreational trips, to 2.2 people from 2.03 in 2001. It remained largely the same, within the margin of error, in other categories.

Although the number of all automobiles in the United States rose from 107 million to 113 million between 2001 and 2009, the percentage of households with no vehicle or with just one vehicle also rose during those two years, from 8.1 to 8.7 percent and 31.4 to 32.3 percent, respectively. In 2009 36.3 percent of households had two vehicles, while 22.7 percent had three or more, both slight declines from 2001. There is generally a higher correlation between areas of high population density (where public transportation is more likely to be available and comprehensive) and households with no vehicles. Since 1995, about two-thirds of households in the least densely populated areas have had at least two vehicles.

Though the number of workers increased from 2001 to 2009, the annual commute vehicle trips per worker declined, and the total number of commute vehicle trips remained substantially the same: 51,699,000,000 in 2009 versus 51,395,000,000 in 2001. Commute drives per worker declined from 354 per year to 342 per year, and commuting vehicle miles as a percentage of total vehicle miles remained about the same at 27 percent. Total commute VMT in 2009 was 623,479,000,000, up slightly from 614,548,000,000 in 2001 (which was a decline from 1995's peak of 642,610,000,000).

Driving remained overwhelmingly the most common form of commuting—89.4 percent, down slightly from 90.8 percent in 2001—as it has been for as long as the FHA has been conducting transportation surveys (the low of 87 percent was experienced in 1977, in the wake of two significant gasoline crises). Most of those who drove, drove alone.

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See Also: Commuting; National Household Travel Survey; Noncommuter Travel; Privately Owned Vehicles; Traffic Impact Assessments; Travel by Households; Travel by Mode; Travel by Persons; Travel Destinations; Travel Patterns by Income; Travel Patterns by Race/Ethnicity; Travel Patterns of the Elderly; Travel Patterns of Women.

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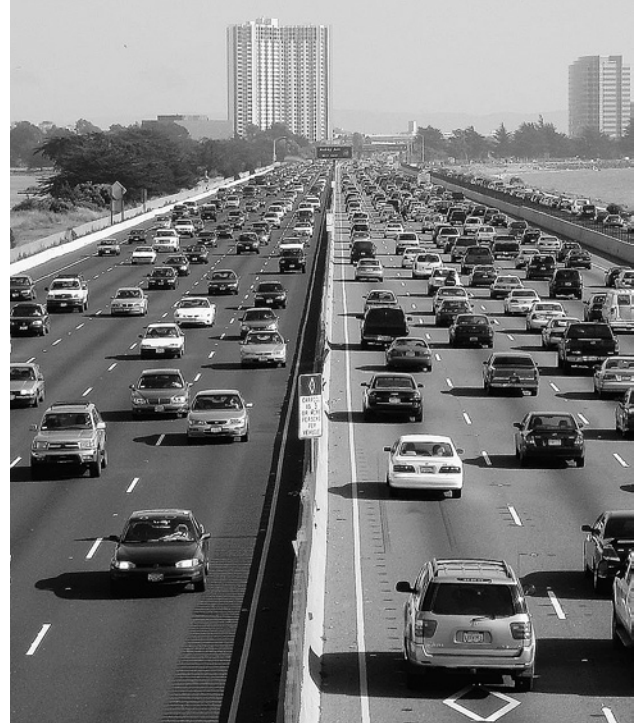
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Automobile Trips

Everyone needs to travel to satisfy economic and social roles. The number of journeys we make to work, to shop, for education, for leisure, etc., has remained remarkably constant over the last 50 years at about 20 per week. As the real cost of travel has reduced, we have traded longer journeys for less dense housing developments. This change was only possible due to the near universal ownership of automobiles in developed countries and massive public expenditure on new roads. If the journey, for example, to work, is the utility of travel, the time and cost taken is the disutility. We undertake an elaborate calculus in trading off this disutility, including being stuck in traffic jams, against the benefits of nicer housing.

Social Aspirations

After a house, a car is the second-largest life expenditure people make, and a signal of social status that is parked outside one's house, advertising one's perception of social standing. Indeed, auto makers spend a lot of money finding out about people's aspirations and playing to these in advertising. Fifty years ago a car advertisement would show a happy family in a new car driving along the highway. Today the highway is so congested that such ads are avoided. Cars are now advertised in fantasy situations, in the mountains, with clean air and beauty.



Interstate 80 near Emeryville, California, in May 2005. A freeway can usually accommodate about 800 cars per hour per lane, or the equivalent of 960 people per hour per lane.

Economic Factors

In real terms the cost of owning and driving a car has declined over the last 50 years, allowing most families to own a car. Indeed, car ownership is still rising, as multicar households become the norm. This growth of car ownership has been enabled by the cheapness of fuel, which does not reflect the replacement cost of petroleum extraction. Not only is car manufacture, maintenance, and servicing a major employer but auto taxes are an important source of government tax revenue. Governments therefore have had strong incentives to encourage more car ownership and use. Now, however, environmental factors are beginning to cause public health and energy security worries, as most cars are 100 percent dependent on oil.

Distribution of Activities

Where we drive depends on where we live and the distribution of the activities we need to access. These are geographically distributed, influenced by market forces and public economic and planning policies. Walter Christaller's "central place theory"

predicts that high-economic-level activities gravitate to the most accessible nodes of a transport network, in order to capitalize on the largest possible market. Before freeways, these central nodes were major intersections and large stations in the central business district (CBD). Today freeway intersections are the prime location of shopping malls, and distribution depots, where internal economies of scale are possible. Such nodes of course are easily served by cars and trucks, but very difficult for transit, unless a new line is built. This suburban decentralization of high-level activities has weakened the CBD, where road access and parking is more limited.

Transport Purpose

The most important trip purpose is the journey to work, since this provides the economic basis for family life. The automobile has widened the job choice area possible within a one-hour drive time, which is about the average people are willing to commute. Conversely, the availability of an automobile to drive to work decreases the importance of house location, so that families can relocate to exploit better schools or lower housing prices, trading off commute costs against mortgage payments. The second most frequent trip purpose is for education, school or college. For small children in one-car households this means living within walking distance of school or a school bus service. The growth of multicar households means that many children are driven to school and so do not have enough exercise.

Individual and Shared Trips

The average automobile has about 1.2 people for work commute trips and 1.4 for other trips. As the driver is one of these people, it means that most automobile use is single-person travel. For the morning and evening peak such single-person car travel congests roads. A freeway in free-flow conditions can accommodate about 800 cars per hour per lane. In the peak period this is equivalent to 960 people per hour per lane, or about 20 buses.

No wonder many highway authorities have installed bus and other HOV (high occupancy vehicle) lanes to increase the peak period passenger capacity of roads. With few exceptions, such HOV lanes have the effect of worsening congestion on the remaining road lanes, as few

commuters will switch to buses and not enough are willing to share a car to reduce flows on non-HOV lanes. More constructively, encouraging car sharing at workplaces can increase average occupancy to over 1.5 people, or a 25 percent reduction in car use. For companies, this can be a useful economic benefit in releasing parking space at the workplace, which can be used for cost-effective expansion. Such car sharing programs can work best with company incentives.

Family outings for vacations by car are a small minority of trips made but, of course, improve car occupancy. Other long-distance trips by car are also a small proportion of trips, with trips over 50 miles (80 kilometers) being typically less than 5 percent of all trips made. Such long trips made for work purposes are usually single occupancy. There are some examples of informal and organized ride sharing, so that the driver can share the car with a passenger, who pays part of the fuel costs of the trip, therefore providing a financial benefit to both parties. The most informal ride sharers include hitchhikers, which forms a very small minority of trips.

Even in carless households, often trips by car outnumber those by transit, as neighbors, friends, and family provide rides. This is particularly so for elderly people who may not be able to drive for health reasons.

Trip Length and Alternative Modes

The economic incentive to maximize the use of a car is great, since the largest costs—purchase, tax, and insurance—are fixed and the marginal costs—fuel and maintenance—are smaller and depend on distance driven. Indeed, most people do not know the real cost of driving and only think in terms of fuel costs, which are typically less than half of total costs. Therefore, unless there is a distress factor, like illness, or someone's car has broken down, people rarely think of alternative modes when a car is available. The one exception to this is the use of park and ride to use rail transit to the CBD or for a longer business trip.

Given that over half of all car trips are under about 10 miles (16 kilometers) long, rarely will alternative modes be competitive terms of travel time and convenience, unless traffic congestion is chronic. The most widely used alternative to the car is the taxi, a form of public transit often overlooked. In many developed countries the taxi is the most

widely used mode of transport by lower income, carless households. In many U.S. cities taxis are the only form of publicly available transportation.

Environmental Impacts

Peak period traffic congestion has severe environmental impacts, of which air pollution has the most health-threatening results. Cardiovascular and respiratory diseases caused by traffic pollution kill on order of magnitude more people than road crashes. This air pollution killing is more insidious than car crashes. Los Angeles is the world leader in automotive petrochemical air pollution, where typically more than half of the year levels of air pollution are above danger levels, and any outdoor exercise including walking is strongly discouraged. All developed cities with high levels of motorization suffer from the same public health air pollution levels. Had the internal combustion engine been invented in 1998, rather than 1898, it is doubtful that it would have been approved for public use. The main mode of transport before the car, the horse, also polluted but not in a health-threatening manner; its waste products being a useful horticultural fertilizer, and unlike a car, horses are fueled from sustainable sources.

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See Also: Air Pollution, Automobiles; Automobile Culture; Automobile Operating Costs; Automobiles, Passenger; Buses; Car Sharing; Carpooling; Commuter Paradox; Commuting; Environmental Impacts; Traffic Congestion; Traffic Psychology.

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Automobiles, Passenger

The passenger automobile, most commonly known as the car, is a wheeled motor-powered vehicle, which is designed to be driven—primarily along roads—and carry passengers. The word *automobile* is of French origin, from the ancient Greek *autos* meaning self and the Latin *mobilis* meaning an entity that can move itself; the term was first used in the context of passenger transport at the turn of the 20th century.

The introduction of the motor car fundamentally changed society when it began to arrive on city streets in 1885. It subsequently became the dominant mode of personal travel around the world. It reshaped cities from relatively bounded areas of economic activity to vast sprawling urban metropolises; it figuratively made countries and continents much smaller and changed where we live, work, and go about our daily lives. Today the availability of cars of all shapes, sizes, and varieties is vast. We have vehicles that are powered by different fuels with different technological characteristics.

The automobile sector is an important contributor to the global economy. It was estimated in 2010 that there were over 1 billion vehicles in the world, and it is expected that by 2015, the global car market will exceed \$5 trillion in value. On the whole, car ownership is increasing, as more emerging economies build roads and cities following the Western model. The car became the cultural symbol of progress in the 20th century—car ownership was synonymous with prosperity.

The status accorded to the personal automobile endures in society today, despite some of the now-known inherent problems with what Daniel Sperling and Deborah Gordon have called our auto "monoculture." Indeed, the changes brought about by the car have been both positive and negative; while the car has played an important role in both creating jobs and growth and enabled people to travel, it has also contributed significantly to air pollution and the associated health impacts as well as greenhouse gas emissions, which are contributing to climate change. Moreover, the roads built to service the growth in cars have transformed landscapes and perpetuated social inequalities the world over.

Although the automobile can be dated back as far as the 1760s—with the creation of steam-powered automobiles—the conventional internal

combustion engine (ICE), like those ubiquitous in our vehicles today, emerged in the early 1880s—running on fuel gas. Gasoline/petroleum-fueled engines emerged and gained prominence around 1885. Vehicles running on electricity were common around the turn of the 20th century, but the increased use and promotion of the ICE led to the demise of the electric engine until it began to emerge again toward the end of the 20th century as air pollution, energy security concerns, and the need to reduce greenhouse gas (GHG) emissions became apparent. Electric vehicles have begun to come on the market as an automobile that potentially could address some of these social and environmental concerns.

Modern History

The modern age of the passenger car is said to have begun in the 1880s, when German inventor Carl Benz created the Benz Patent-Motorwagen. Such was the popularity of Benz's invention that horse-drawn vehicles, which were the most common form of the transport at the time, were gradually phased out, for the wealthy at least. Development of similar technology was beginning to take place across Europe and also in the United States, and it was in 1897 that Rudolf Diesel—another German—created the first “Diesel Engine.” Indeed, there was a vibrant competition between the fuels during the early period of expansion, with steam, gasoline, and electric vehicles all seeking dominance in the emerging market.

All were viable technologies, but in the early 1910s, gasoline won the battle and has been the leading power source for the global vehicle market ever since. Part of the reason for this may well be due to the fact that in 1908, Ford Motor Company introduced the Model T. Ford's pioneering “production line” manufacturing techniques, which significantly sped up production, enabled the cost of owning a vehicle to be dramatically reduced, and enabled the ownership of a passenger automobile to become a possibility for the masses. The process, which included placing a worker at a distinct point with one specific duty on the production line, became known as “Fordism” and was copied by other manufacturers in the car industry, as well as by many other industries.

Only when Japanese manufacturers pioneered “just-in-time” or “lean manufacturing” processes

was the production line called into question. Such processes reduce the need to keep significant stock on hand and allow the manufacturer to supply a minimal level of products to maximize return on investment—enough to sell but with no left over or latent stock.

Although the typically black Model T fell from favor when a larger range of models and color choices from other manufacturers, including General Motors, entered the market, it is nonetheless responsible for initiating the pervasive spread of the car around the globe and changing our senses of and relationships with space and movement for good. In the early 1920s, after the end of World War I, it was estimated that some 2 million cars were bought every year in the United States alone. By the end of the decade, more than half of all American households owned a car; 20 percent owned two cars. However, the Depression curtailed the rise in car ownership, and World War II saw the car companies retooling so as to provide necessary munitions and turning production away from passenger vehicles toward tanks, airplanes, and the like.

Since the end of the war and until fairly recent years, global car ownership has continued unabated. Road infrastructure has been built to keep pace with the constantly increasing motorization, but demand continues to outgrow the supply of road space, with congestion a fairly ubiquitous problem in cities around the world. And the recent wealth acquisition in rapidly developing economies like India and China has spurred development of massive new car markets.

Rise to Dominance

Streetcars, bus networks, tramlines—the well-established mass transit systems in particular cities, including Los Angeles—were removed to make way for the increasingly popular automobile in the 1930s. And those cities that were less developed by this time saw road building dominate over the provision of other transportation systems. The U.S. Highway Act in the mid-1950s called for the systematic construction of over 40,000 miles of interstate roads to be built across the country; this sealed the dominance of the automobile as the primary mode of choice, and across the Western world the car has become dominant. With the large-scale increase in the construction of roads

and associated infrastructure for the car, including parking and fueling infrastructure, most cities and neighborhoods have been shaped by the car and function around the road network. In many urban areas, provision to travel by other modes is missing or poor and walking and cycling infrastructure does not exist, enabling the dominance of the automobile.

Yet the passenger car has become more than just a mode of transportation. Car ownership is accorded great status as a provider of freedom and has been served and promoted by iconic images of the open road. This symbolism associated with car ownership first seen in the late 1940s and early 1950s has endured over the past 60 years. Similarly, the racing of automobiles has been a commonplace activity since the early advent of the car, with the first organized race taking place in France in 1887. But over the past 100 years, several types of international car racing have evolved and gained popularity, typifying and emphasizing the freedom and enjoyment that can be derived from driving, and promoting luxury and sports car markets around the world. Performance is often a key criterion in the selection of a car to purchase, with top speed and road handling of the car important to buyers, alongside considerations of fuel economy and price.

Congestion, Emissions, and Capacity

As early as the 1960s, at a time when much of the road network was still under construction, it was becoming increasingly apparent that the automobile was having health impacts, causing particular environmental harms and social impacts through its dominance. As the road infrastructure being built became congested at peak periods of the day, the impacts of the traffic building up began to emerge. Smog caused by a photochemical reaction occurring between the pollutants produced by the exhaust fumes of cars running on gasoline and sunlight is responsible for respiratory illness and reduced lung capacity in many global cities. Such health considerations were not understood at the time when urban areas were being filled by automobiles as they became more affordable throughout the 20th century.

As more roads were built to service the increasing population of car owners, significant social inequalities have developed through not only access

to vehicles but also the segregation of communities through road building. Cars are also a significant contributor of greenhouse gases, the primary cause of human-induced climate change.

Move to Alternatives

Since the impacts to health caused by traffic congestion and the internal combustion engine have been realized, the industry has made significant improvements to both the vehicles and the fuels powering the cars—developments such as the catalytic converter and the introduction of unleaded gasoline have greatly improved conditions over the last few decades. But bearing wider issues into consideration, like energy security, peak oil, and climate change, for the last 30 years efforts have been under way to find viable alternatives to the internal combustion engine and automobiles that run on fossil-based fuels like gasoline and diesel. There are particular trade-offs between particular alternatives; for example, while diesel is considered a more efficient fuel than gasoline, it is a more significant contributor to local air pollution that is detrimental to health. Similarly, advances in biofuel vehicles have raised concerns over the competing needs of growing crops for food and crops for fuel. Advances have been made in powering vehicles with gas—both compressed natural gas (CNG) and liquefied petroleum gas (LPG)—but this sector of the total vehicle fleet remains peripheral.

Over the past 10 years, more attention has been paid to the electrification of the car fleet, taking a lead from California's zero-emission vehicle (ZEV) mandate that was introduced in 1990. The Toyota Prius led the way in the late 1990s, offering the first mainstream hybrid vehicle with an internal combustion engine for longer journeys and a battery for city driving. Several of the larger car manufacturers have brought electric vehicles to market over the past few years, including the Nissan Leaf and the Chevrolet Volt; similarly, new manufacturers have entered the market like Tesla, with its luxury brand Roadster and symbolically named Model S.

While the market continues to be dominated by conventional vehicles, recent legislation such as the European Union cars and carbon dioxides (CO₂) standards and the newest iterations of the Corporate Average Fuel Economy Standards in the United States calling for more and more stringent fuel efficiency, vehicle-based technological improvements

and so-called light-weighting brought about through new materials will likely only get the auto manufacturers part of the way; they will need to continue to look to new fuels—electricity, second-generation biofuels, and even hydrogen—in the long term. These standards do not address the impacts that stem from the fact that people continue to drive more and farther year on year or the social or environmental impacts of the road infrastructure itself. Moreover, the shift toward new fuels suggests that the automobile will remain the dominant choice of transportation for decades to come.

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See Also: Automobile Trips; Privately Owned Vehicles; Single-Occupant Vehicle Trips; Smart Cars; Traffic Congestion; Vehicle Miles Traveled.

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national government owns some or all of the major commercial airlines, but in the United States all the major airlines are privately owned and operated. Such status is subject to change: British Airways, for example, was a government entity when formed in 1974 from the merger of two state-owned major operators, British Overseas Airways Corporation (BOAC) and British European Airways, along with two regional airlines. However, British Airways was sold to private industry in 1987.

Scope of the Industry

Commercial aviation in the United States is estimated to generate some \$1.3 trillion in economic activity, or about 5 percent of the total U.S. gross domestic product (GDP). According to the Federal Aviation Administration (FAA), the industry employs or supports the employment of more than 10 million workers. As a factor in global trade, the industry exports about \$75 billion annually in aircraft engines, equipment, and parts—the leading single sector of net exports by U.S. industries since the late 1990s.

The United States has in recent years contributed from one-fifth to one-fourth of total global commercial aviation economic activity. Some of this is indirect. For instance, air passengers within and from the United States spend about \$250 billion on goods and services that they might not otherwise spend if they did not travel by air, the FAA reported. In addition, commercial aviation is a driver of domestic and international manufacturing and retail trades by transporting more than \$550 billion in freight annually.

For several decades at least, commercial aviation has not only driven economic expansion but it also has been a leading force in shaping the very nature, structure, and dynamic systems of the urban, regional, and many rural areas of the United States and other countries. Other modes of transportation have also influenced the overarching trends, but air travel and air transport have exerted a particularly profound influence on the ways and means of interurban, regional, and international commerce in its many ramifications: social, political, architectural, and with regard to policy in the domains of energy, environment, employment, and national security.

Air transport and air travel—the main constituents of commercial or business aviation—exert a

Aviation, Commercial/Business

Commercial aviation composes the largest sector of nonmilitary aviation by economic production value; it includes airline passenger travel, air cargo traffic, charter flights, and additional business-oriented aspects of general aviation. In many countries, the



A Delta Airlines Boeing 747-400, along with ground operations vehicles and several other aircraft, on the runway at Atlanta Hartsfield-Jackson Airport, which is the world's largest with a 2.2-million-seat capacity. The five largest airlines in the world by capacity are based in the United States and include Delta, United, Southwest, American, and US Airways, with a combined 15.5 million seats.

multiplying effect on other sectors of the economy, including but not limited to manufacturing and high-tech research, wholesale and retail trade, construction, hospitality, leisure and entertainment, and various institutional sectors such as education and health care.

Capacity of Carriers and Airports

The top five world airlines by capacity (that is, seats offered) are all based in the United States: Delta, United, Southwest, American, and US Airways. Together these five command some 15.5 million commercial passenger airline seats—equivalent to the next 11 major carriers combined. These next-in-line carriers include China Southern and China Eastern, Lufthansa, Air France, All Nippon, and representatives of other regions.

Only one of the top five airports by capacity offered is in the United States; however, it is the world's most capacious—Atlanta Hartsfield-Jackson. This global hub with 2.2 million total seat capacity is just ahead of Beijing Capital International Airport. Other contenders in the top five are Tokyo Haneda, London Heathrow, and Dubai International.

In the United States, the FAA listed 503 commercial service (CS) airports in its most recent National Plan of Integrated Airport Systems (NPIAS) report. These include both the 382 primary airports, defined as handling more than 10,000 enplaned passengers per year, and the 121 nonprimary CS airports, with annual enplanements ranging from 2,500 to 10,000. The primaries are staggered in size range, classified by the

percentage of total annual U.S. enplanements; these are termed nonhubs, small hubs, medium hubs, and large or major hubs.

Outlook

Industry leader Boeing Corporation in mid-2013 projected a 5 percent annual growth rate for both passenger traffic and cargo traffic worldwide over the next 20 years, and estimated that more than 35,000 new aircraft will be in demand, at a value of approximately \$4.8 trillion. This major manufacturer pointed to wide-body aircraft as the likely answer to many carriers' goals of increasing capacity while cutting fuel consumption. Boeing also projected that Asia will be where the most rapid expansion of the industry continues to take place and will account for more than one-third of all new aircraft deliveries over the coming two decades.

The Boeing projection roughly paralleled a report in 2011 by European rival manufacturer Airbus, which also predicted an approximate 20-year doubling of the worldwide commercial fleet. At the time, Airbus said that demand would equate to some 28,000 new aircraft with a value of about \$3.5 trillion. The Toulouse, France-based company envisioned revenue passenger mileage expanding by nearly 5 percent annually over the next 20 years, another perspective on the doubling of air traffic by 2030.

In sync with the later Boeing analysis, the Airbus projection foresaw Asian-market volume making up about one-third of the total traffic. In particular, the analysts at Airbus projected the U.S. domestic flights to log 11.1 percent growth, followed by India at 9.8 percent air traffic growth, western Europe at 7.5 percent, and China at 7.2 percent.

The Centre for Aviation (CAPA) in its 2013 outlook identified Persian Gulf commercial air carriers as poised for continued strong growth, along with those in China, and to a lesser extent the carriers in the emerging national economies in India, Africa, eastern Europe, and Latin America. The report was not entirely positive, however, as it led with the observation that many major commercial airlines are operating in a risk-reduction mode as opposed to an aggressive or optimistic growth phase.

This analysis stems from several years of a somewhat lagging volume curve in the wake of the global financial distress that began in 2008, with its lingering atmosphere of general economic uncertainty.

Fully 15 percent of premium commercial air passenger traffic vanished in the immediate wake of the 2008 crisis—and there has been scant recovery of this vital source of global aviation revenues in the five years since.

Layered over the background uncertainty, CAPA noted, was the persistent upward pressure on fuel prices and a still-lackluster demand level for commercial air service in the developed economies of Europe and North America. The report indicated that even for fuel prices to hold at current levels would be a positive benefit, and noted that fuel surcharges added to customer tickets were more of a travel agency fee—neutralizer than any real savings or gain to operating incomes. The report cited the real threat of secondary route reduction and other cost-cutting measures that numerous air carriers would be compelled to take should fuel prices spike or trend strongly upward. Tertiary threats included what the industry considers relatively high tax structures, somewhat high labor costs, and in some regions a marked evidence of too much capital sunk in fleets and infrastructure—in other words, a condition of overcapacity.

The CAPA analysis painted European operations as heavily in debt, U.S. carriers “forging a shaky recovery” but also debt ridden, but Asian operators as better positioned cash-wise and enjoying various incentives. The report concluded that most major carriers have already enacted policies to cut risk by building partnerships and ancillary business, hedging on cash flow, improving their lease positions, and, above all, squeezing capacity—hence the strong inherent demand for new wide-body jets as detected by the manufacturers' reports.

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See Also: Air Passenger Carriers; Air Traffic Control; Airline Pilots and Crews, Labor Issues of; Airplane Pilot Training; Airport Hubs; Airport Planning; Economic Development; Economics of Air Travel; Federal Aviation Administration; Fiscal Politics; Globalization; Next-Generation Airports, Federal.

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aviation is part of the larger realm of general aviation, which as a whole contributes on the order of \$75 billion annually to the U.S. economy, according to the Federal Aviation Administration (FAA). This figure includes operations of nearly \$39 billion and combined manufacturing and traveler expenditures of approximately \$37 billion each year.

Research by the FAA has shown that average annual earnings of private aviation workers—both those directly employed in private aviation and those working for support enterprises from manufacturing to distribution to ground services—are nearly equivalent to the earnings of workers in similar positions within the commercial aviation industries, both direct and ancillary.

In its 2011–2015 National Plan of Integrated Airport Systems (NPIAS), the FAA indicated that 2,829 public airports in the United States are designated as "reliever airports" or as general aviation airports, that is, they offer noncommercial service only; specifically, 2,560 general aviation airports and 269 reliever airports. To be listed in the NPIAS, general aviation airports must be open to the public, be located within 20 miles of the nearest NPIAS-listed airport, and base at least 10 aircraft. Reliever airports must base at least 100 aircraft or at least 25,000 itinerant operations annually. These nearly 2,900 GA and reliever airports make up more than half of all public airports in the United States.

The aircraft of choice in private aviation tends to be of the piston engine type. Roughly 60 percent of GA flight hours were conducted in piston-driven fixed-wing craft; the remaining 40 percent of flight hours were accomplished in roughly equal parts by turboprop, jet, and rotorcraft.

Aviation, Private

Private aviation is a component of general aviation (GA), which also encompasses such noncommercial segments as search and rescue, law enforcement, medical transport, and emergency evacuation. Agricultural aviation is also considered within GA.

Infrastructure and Fleet

There are an estimated 39,000 private aircraft worldwide; as many as 1 million people in the United States work within or in association with the private aviation industry. The domain of private

Private Pilot Qualifications

In most countries, private aviation pilots must obtain certification by a national licensing body. The pilot must determine the type of aircraft for which he or she wants to earn the certification; these range from gliders to airplanes to helicopters, and other flight devices. Beyond the initial private pilot certificate or license, a pilot may decide to qualify for additional levels of ranking, rating, or endorsements. These add-ons may cover qualification for such skill sets as instrument-only piloting, for example, or may be specific to certain aircraft configurations, such as single- versus multiengine craft, or to high altitude-capable pressurized aircraft.

Supporting requirements in addition to the pilot license itself typically include qualifying for such documents as medical certificates. These are classed by criteria based on age, vision, hearing, and other essential health metrics. Some types of certification are nonpilot types; these can apply to flight engineers, instructors, dispatchers, attendants, and related professions. Some of these have distinct rating or class certifications.

The FAA recorded more than 610,000 active airman certificates (pilot licenses) in the United States at the end of 2012. Of these, approximately 188,000 were private aviation pilots, 116,000 were commercial aviation pilots, and nearly 146,000 were certified as airline transport pilots, the highest rating.

Slightly more than half of all active airmen certificates had instrument flight ratings. Nearly one-fifth of the total active certificates were student pilot licenses. In addition to the pilot certificates, there were more than 701,000 active nonpilot certificates, of which nearly half were certified as mechanics; flight attendants were the next-largest cohort, at 172,000, followed by ground instructors, flight engineers, repairmen, dispatchers, and others.

From DIY to Luxury

The scope of private aviation extends from the garage mechanic, do-it-yourself types who build and fly ultralight aircraft, to the elite pilots and owners of sleek executive jets and jet helicopters. Most participants in private aviation, however, are found somewhere in between. Owners and operators of private aircraft must pay airports for the use of runways, terminal space, and other facilities.

While some private pilots own—or even build—their own craft, many rent or lease them. At the higher end of the price spectrum, where individual aircraft may be valued in excess of \$10 million, to say nothing of operating costs, the phenomenon of fractional ownership is popular. While a practical solution, fractional ownership has also given rise to certain contention over tax issues, based on the question of whether such scenarios represent true private aviation or are actually more of a commercial enterprise.

The budget of the FAA is supported in part by a tax on airline passenger tickets. The fact that such a tax is not applied to private aviation passengers, while sensible when considered broadly, is nevertheless at the root of this controversy. One recent

prominent case was the contention between NetJets—which along with its ancillary firms operates the world's largest private aircraft fleet with more than 650 aircraft—and the Internal Revenue Service (IRS), wherein the IRS asserted that the company is at least in part a commercial carrier. NetJets and the IRS wrangled over the issue in 2011 and 2012. Maneuvers toward an eventual settlement featured apparently successful lobbying, for a legislative compromise solution has involved amended FAA guidelines that would add a general aviation fuel surtax, instead of a federal excise tax, on the managers of fractional-ownership air carriers.

There exists the potential for some built-in friction between private and commercial pilots and operators where their paths overlap, in particular, at general aviation airports. Private pilots, for example, often find it difficult to operate at those general aviation facilities that are congested with commercial flight activity, which involves such hazards as aircraft moving at higher speeds and generating higher wake turbulence as well as use of different air traffic control procedures that are chiefly tailored to commercial operators. Recognizing these difficulties, the FAA has made it a policy to encourage development of more general aviation capacity in and near major urban areas; much of this capacity takes the form of reliever airports.

While the FAA and the industry have been somewhat successful in this initiative, it has also meant a diminishing presence of private pilots at such nominally general aviation facilities as the Dallas–Fort Worth, Seattle, and Hartsfield-Jackson Atlanta airports, where they currently make up less than 1 percent of operations.

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See Also: Air Travel; Airplane Pilot Licensing; Economics of Air Travel; Federal Aviation Administration; Vehicle Ownership Models.

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of the U.S. Department of Transportation (USDOT) regulates such certification requirements. The United States is considered to have rather lenient rules on ultralight aircraft in comparison with other countries that use similar technology.

Why Ultralight Aircraft?

Flying ultralights is an exhilarating sport when done safely. It is not associated with the prestige of owning an aircraft but typically is viewed as a sport that allows the passenger to experience flying in a different manner. Many people are interested in flying ultralight aircraft because they are less costly, there is a minimal amount of training required, and it is considered exhilarating to feel the wind in your face, fly low and slow, and enjoy flying a simple aircraft recreationally. Unlike traditional airplanes, which are used to transport people and goods, ultralight craft are used primarily for sport, and the regulations that pertain to them are less restrictive. Pilots face fewer rules and operational systems. In terms of cost, however, while they are less expensive in terms of fuel, it is relative to the distance they travel and not necessarily less expensive than conventional civilian airplanes.

Many question the safety surrounding ultralight airplanes. While they are considered safe, this is dependent upon those who build and develop them following proper standards and procedures. Pilots are responsible, in large part, for their own safety by observing what they feel is incorrect or potentially dangerous. Learning the general behavior of the aircraft is important when one is first training to be able to spot signs of an improper aircraft on one's own. Ultralight vehicles, however, are inherently safer than conventional airplanes in that they simply travel at reduced speeds and have lighter vehicle weights. When accidents arise, however, it is observed that they coincide with other causes of aviation accidents, which result from a lack of proper instruction or training in extreme circumstances.

Aviation, Ultralight

Also referred to as microlight, ultralight aviation is the flying of lightweight aircraft that accommodates one traveler. In developed countries, ultralight airplanes account for the majority of civilian-owned aircraft. In Canada in October 2010, the ultralight aircraft fleet comprised up to 19 percent of the total civilian aircraft registered. The United States does not register ultralight aircraft, although there are certification requirements for both aircraft and pilots. The Federal Aviation Administration (FAA)

Definition and Regulation

Section 103 of the Federal Aviation Regulation (FAR) governs the use of ultralight aircraft and the responsibilities that fall upon their pilots. Ultralight aircraft are intended by the FAA to be used only for sport and recreation, operated in daylight hours, not flown over congested areas, have only

a single occupant, carry a maximum five gallons of fuel, yield right-of-way to all other aircraft they encounter, and obtain permission to fly and operate in controlled airspace and restricted areas. Ultralight vehicles may be operated during the twilight periods—30 minutes before official sunrise and 30 minutes after official sunset—or, in Alaska, during the period of civil twilight if the vehicle has an operating anticollision light visible for at least three statute miles and the flight is only in uncontrolled airspace. Ultralights are defined as weighing no more than 254 pounds of powered empty weight and having one seat, a maximum of 155 pounds of unpowered empty weight, five gallons of fuel capacity, 55 knots of maximum full-power speed, and 24 knots of maximum power-off stall speed. Craft that exceed this definition in any manner are not considered ultralight.

The FAA chose not to regulate and impose many federal regulations regarding pilot certification of ultralight vehicles but rather left this responsibility to the ultralight community, which came up with a number of requirements. Their suggestions have since gained FAA approval. The industry's self-regulation policy, however, relies upon continued compliance from the ultralight aircraft community. It is the responsibility of the aircraft owner to ensure the vehicle is safe to fly. Manuals are available for owners to determine how the FAA determines safety requirements for their particular aircraft. Registration is available through the United States Ultralight Association (USUA).

Pilot Requirements

Similarly, the FAA does not certify ultralight-specific pilot knowledge and proficiency but expects such pilots to complete training under federally recognized programs. The USUA emphasizes that just because flying a lightweight airplane may look simple does not mean that extensive training should not be taken. Ultralight airplanes are identified as planes that only hold one passenger, although the training, whether sport or private pilot licensure, prepares pilots for two-passenger craft. These planes, however, must be registered with the FAA and possess a federal airworthiness certificate.

Instruction for ultralight airplanes usually requires 10 to 15 hours before one is allowed to fly alone. Federally recognized flight schools and instructors are available through the USUA.

Additional regulations include minimum age limits, medical certification, and completion of FAA-guided written, oral, and flight tests.

There are two different licenses an ultralight pilot can obtain: a sport pilot license or a recreational and private pilot license. Sport pilot licenses allow the licenseholder to operate a plane that meets the requirements of a light sport aircraft with a minimum of 20 hours of training; the minimum age to obtain this license is 17. The recreational and private pilot license allows a pilot to carry one passenger in an aircraft. The minimum flight instruction and solo hours are set at 30 hours and, like the sport license, the minimum age is 17. This license can be used only for flying during daylight hours. Fewer than 300 individuals nationwide currently hold this license, and many continue training to receive their private pilot license.

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See Also: Aircraft Design; Airplane Pilot Licensing; Airplane Pilot Training; Aviation, Private; Federal Aviation Administration.

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Aviation Safety, Dangerous Goods Transport and

Dangerous goods are defined as those materials that may cause danger to an aircraft and/or its

passengers if they are carried aboard, either in the cabin or as cargo. Many everyday items actually can be quite dangerous when transported by air. Variations in temperature and pressure during a flight may cause items to leak or break, which may generate toxic fumes or ignite a fire. As a result, many substances, including some seemingly innocuous items, must either be prohibited from air transport altogether or carried aboard only after meeting specified restrictions on their packaging, quantity, stowage location and proximity to other items, and category of flight (passenger plane or freight).

Though some prohibited dangerous goods may be carried onboard an aircraft by passengers who are not aware of the regulations, or who deliberately flout them, there are many permitted items carried aboard aircraft that also have potential for causing or exacerbating a hazardous incident.

Dangerous goods are routinely carried on board both passenger and cargo aircraft. They pose minimal hazard while in transport as long as they are correctly identified, packaged, and handled. If not, those same items could be potentially harmful to all onboard. To ensure safety, it is critical that airline operators take actions to facilitate awareness and education about potential dangers by displaying notices for passengers at airport ticket desks and check-in areas, ensuring that regulations regarding the transportation of dangerous goods are strictly adhered to by all ground personnel and flight crews, and providing detailed procedures for dangerous goods handling and emergencies to all employees who might come into contact with dangerous goods being transported by air.

Dangerous Goods Classifications

The International Civil Aviation Organization (ICAO) was created in 1944 as a specialized agency of the United Nations. Serving nearly 200 member states, the agency promotes the safe and systematic development of international civil aviation around the globe. It is responsible for setting standards and regulations necessary to ensure aviation safety, security, efficiency, reliability, and environmental protection.

The ICAO developed the “Technical Instructions for the Safe Transport of Dangerous Goods by Air” to provide air operators with regulations for transporting dangerous goods. The ICAO defines

dangerous goods as items or substances that pose potential risk to health, safety, property, or the environment. Goods classified as dangerous fall under one of nine hazard classes. Each class, and subsections within each class, is assigned a specific label and iconography that is displayed via a diamond-shaped placard system to ensure speedy and accurate identification. For example, a white diamond with a skull and crossbones identifies poisonous items, a red diamond with a flame symbol is applied to items with potentially flammable liquids and gases, a red-and-white striped diamond with a flame indicates potentially flammable solids, and a blue diamond with a flame indicates goods that are potentially flammable when wet.

The International Air Transport Association’s *Dangerous Goods Regulations* document was developed in alignment with the ICAO technical instructions and provides air operators with a guide for identifying, packaging, and labeling dangerous shipments in accordance with national and international air regulations.

There are nine specific hazard classes for dangerous goods. Class 1 includes explosive substances, explosive articles, and pyrotechnic devices such as fireworks and munitions. Class 2 covers flammable gases, which are gases such as acetylene and hydrogen that ignite on contact with an ignition source; nonflammable gases that do not ignite and are not poisonous; and poisonous gases such as hydrogen cyanide that are likely to cause serious injury or death when inhaled.

The third hazard class for dangerous goods is flammable liquids, which include common items transported via air, such as perfume, alcohol, and fuel. Class 4 encompasses flammable solids like matches, spontaneous combustibles such as coal and linseed oil, and solids such as sodium and potassium that emit a flammable gas when wet or react with water when wet.

Hazard Class 5 includes oxidizing agents that are not natural, such as ammonium nitrate and chemical oxygen generators. It also includes organic peroxides, such as fertilizer and pool chemicals, that may be explosive or burn rapidly due to their thermal instability, sensitivity to impact and friction, and dangerous reactions when coming into contact with certain other substances. Class 6 hazards include toxic substances like pesticides, which are apt to cause death or serious injury if swallowed,

inhaled, or absorbed through the skin. Infectious substances known or likely to contain pathogens such as bacteria, virus, or medical waste are also included in this category.

Classes 7 and 8 address radioactive materials and corrosives, respectively. Corrosive substances are found in commonly used and transported items such as batteries and can corrode certain metals and dissolve human skin and other organic materials. The final hazard class covers miscellaneous items such as dry ice and magnets. Anything from firearms to scissors that is or could constitute a weapon is also prohibited within airplane cabins.

Airline passengers and crew members are allowed to carry a limited amount of dangerous goods classified as hazardous for their personal use within carry-on luggage. Such items include perfume, nail polish, nail polish remover, small lithium and lithium-ion batteries used in portable electronic devices, alcoholic beverages with an alcohol content below 70 percent, and dry ice used to refrigerate perishables. Fire extinguishers, oxygen for masks, and carbon dioxide gas for inflation devices are other hazardous materials that are permitted within the airline cabin in accordance with regulations due to their roles in onboard emergency response.

ICAO Technical Instructions

The ICAO “Technical Instructions for the Safe Transport of Dangerous Goods by Air” contain detailed instructions to ensure the safe global transport of dangerous goods by air. The requirements are based on the dangerous goods classification system and air transport status. Air transport status refers to goods that are forbidden for air transport under any circumstances, forbidden on aircraft in most circumstances but could be exempted in exceptional circumstances, forbidden on passenger planes but allowed on cargo aircraft, and not forbidden at all on either passenger or cargo aircraft under normal circumstances.

As required by the technical instructions, all dangerous goods must be packaged appropriately and may be subject to quantity restrictions according to the degree of hazard and the type of aircraft—passenger versus cargo—on which the items are being carried. For example, U.S. air passengers are permitted to carry on one 1-quart-sized clear plastic bag per person to accommodate liquids, aerosols, and gels, and those items are restricted

to containers of 3.4 ounces or smaller as a security measure to protect against potentially damaging dangerous goods volumes and interactions. Airport personnel at passenger screening checkpoints are required to ensure compliance with the regulation and conduct additional screening as needed.

There are strict requirements for the marking and labeling of dangerous goods packages and for the documentation that must be prepared whenever hazardous packages are conveyed by air. The ICAO technical instructions require that every package of dangerous goods be inspected externally by the aircraft operator or its contracted agent before transport to ensure compliance with regulations. Packages identified as dangerous goods are subject to loading restrictions, including segregation of packages containing incompatible dangerous goods and special securing of packages in place to prevent movement during flight.

The technical instructions mandate that the aircraft pilot should be informed prior to flight departure about dangerous goods that are on board as cargo and where in the plane they are located. If an onboard emergency arises, the pilot is required, if feasible, to notify air traffic control of the presence of any dangerous goods on the aircraft. The measure is intended to facilitate appropriate emergency response if such services are needed. Air operators are required under the technical instructions to report to the relevant authority all accidents and incidents involving dangerous goods. In turn, each jurisdiction is required to have procedures in place to investigate such occurrences.

The technical instructions include training requirements that apply to all parties involved in dispatching, handling, and transporting passenger baggage or cargo goods classified as dangerous. The requirements include the need for refresher training every two years and the maintenance of specific training records. Shippers must ensure that personnel who prepare loads of dangerous goods receive training or must use the service of another organization whose staff is sufficiently trained. Air operators must ensure that their own personnel and the staff of their handling agents are trained accordingly. All dangerous goods training programs for air operators are subject to approval by the carrier’s contracting state, which is also responsible for inspection and enforcement procedures among its air operators to ensure all

dangerous goods are conveyed in full compliance with the international requirements to ensure consistent safety standards worldwide.

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See Also: Air Cargo Carriers; Air Passenger Carriers; Airplane Disasters; Airport Administration; Airport Security; Aviation Safety, Wildlife Strikes and; Federal Aviation Administration; Freight Transport, Security Issues; Pipeline and Hazardous Materials Safety Administration; Security, Transportation; Terrorism, Transportation Systems as Targets of.

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Aviation Safety, Wildlife Strikes and

Since the inception of powered flight on December 17, 1903, wildlife strikes in aviation have resulted in hundreds of human deaths and billions of dollars in damages. Orville Wright reported the first bird strike as early as 1905. Since that time federal agencies, airport authorities, biologists, and pilots have been involved in the investigation, reporting, and solutions to wildlife strike research and mitigation.

The most costly crash to date in terms of lives was Eastern Airlines Flight 375 and occurred on October 4, 1960. The Lockheed L-188 Electra, a four-engine turboprop, struck a flock of European starlings six seconds after takeoff. The relatively small blackbird-sized starlings caused engine damage to three of the four engines and the aircraft subsequently crashed into Boston Harbor, resulting in 61 fatalities.

A wildlife strike can be defined as the impact between an animal of size substantial enough to result in damage to an aircraft. Approximately 97.4 percent of all wildlife strikes involve birds. Other animals involved in strikes include mammals such as foxes, coyotes, alligators, and deer at a rate of approximately 2.4 percent. Reptiles such as turtles, tortoises, and alligators accounted for only approximately 0.2 percent of all strikes. Wildlife strikes can cause damage to engines, landing gear, and structural components of an aircraft. Engines account for 32 percent of all damaged components and in many cases cause either a partial or complete loss of power, resulting in the aircraft not being able to maintain altitude.

The most common type of bird involved in strikes is the gull, accounting for 25 percent of birds identified in bird strikes. The second most common type of bird identified in strikes, approximately 14 percent, are doves and pigeons of various species, followed by raptors at 12 percent, waterfowl at 10 percent, blackbirds/starlings at 10 percent, and all others comprising a mix at 29 percent.

The majority of bird strikes, 92 percent, occur at or below 3,000 feet above ground level (AGL). Within this altitude range, 61 percent occurred 0 to 100 feet AGL, 12 percent occurred between 100 and 500 feet AGL, and 18 percent occurred at 500 to 3,000 feet AGL. Strikes during the approach and landing roll occurred at a rate of 58 percent. Takeoff and initial climb phase accounted for 38 percent of strikes.

Bird strikes tend to occur during the day at a rate of 58 percent. Annually, most reported bird strikes (51 percent) occur between the months of July and October. In contrast, mammal strikes (64 percent) tend to occur at night between the months of August and November. White-tailed deer are responsible for approximately 33.6 percent of all mammal strikes. Even though they represent a small percent of total strikes, deer are a major hazard to an aircraft structure due to the mass that they present in comparison to birds or small mammals. Just as with birds, the landing roll held the highest risk for mammal strikes at a rate of 52 percent.

Identification

Wildlife strikes are reported on a voluntary basis to the Federal Aviation Administration (FAA) via paper

or Internet form. Reports can be filed by pilots or airport personnel. Remains that cannot be identified by airport personnel can be sent to the Smithsonian Institution Feather Laboratory for identification. All reports are reviewed by an FAA staff biologist. The data is kept in the FAA Wildlife Strike Database that is managed by the U.S. Department of Agriculture and can be queried online back to the year 1990. Currently, approximately 45 percent of birds involved in strikes are identified at the species level. Voluntary reports are estimated to account for only 20 percent of bird strikes and \$123 million in annual cost to operators. An extrapolation of that number could be as high as an actual cost of \$614 million annually.

Identification of species involved in a bird strike is crucial to the ongoing effort to prevent bird strikes. Understanding local as well as migratory bird habitats and bird behaviors is a key element in developing and maintaining ongoing mitigation programs. Identifying species involved in a strike provides data for researchers and biologists to investigate in terms of local sight survey, as well as in the analysis of regional flyways.

Identification of species at the Smithsonian Institution Feather Identification Lab can be accomplished through several methods. Often the impact in a strike is violent and remains are limited to blood and feathers. The lab can first use microscopy to examine the downy feathers of the bird. Downy feathers, which are smaller feathers found under the tougher exterior feathers, are unique to different groups of birds and can be used to narrow the species for identification. Further identification includes DNA sequence analysis against the Barcode of Life Data Systems database. Identifying exact species may require the assistance of the Feather Laboratory due to the vast number of species that can exist within a family of bird. The dove and pigeon family of birds *Columbidae*, for example, include 310 known species.

Assessment

After examining all wildlife strikes reported to the FAA, the FAA staff biologist examines the strike history at particular airports that stand out in the data. The staff biologist then forwards a report of data to the appropriate regional personnel in the FAA Office of Safety and Standards. From that point, operators of certified airports are required by regulation to conduct a wildlife hazard assessment.

Under 14 CFR Part 139, airports are typically required to be certified by the FAA if they serve scheduled and unscheduled air carrier aircraft with between nine and 30 seats and are required by the FAA administrator to have a certificate. However, the regulation does allow the FAA to issue certain exemptions to airports that serve few passengers yearly and for which some requirements might create a financial hardship.

The wildlife hazard assessment includes a survey of the airport as well as surrounding areas. Site surveys include marshes, wetlands, waste disposal and trash transfer facilities, underwater discharges, stormwater runoff, and livestock production. Natural marshes and wetlands are habitats for both migratory and nonmigratory birds. Waste disposal and trash transfer facilities are major attractants for scavenging gulls. Stormwater runoff and underwater discharges are attractants for wading raptors that feed on small fish, reptiles, and insects that reside in the shallows of these types of habitats. Larger raptors are less prevalent, but the impact of a blue heron, weighing up to seven pounds, can create heavy structural damage.

Livestock production is an attractant for symbiotic birds such as the cattle egret. The cattle egret follows cattle, horses, tractors, and vehicles and preys on the insects that are stirred up in their wake. A natural feed site therefore also includes the edges of roads and runways. Based on the assessment, a wildlife hazard management plan may be required by the FAA administrator for the certified airport.

Management

A wildlife management plan identifies key personnel involved in implementing and maintaining the plan. It also includes identification of hazardous wildlife attractants on or near the airport, appropriate wildlife population management techniques, a recommendation of necessary equipment and supplies, and training requirements for airport personnel involved. Finally, the plan identifies when and how the wildlife management plan will be reviewed and updated.

Wildlife population management techniques include flight schedule modification, habitat modification, resource protection, repelling/exclusion, and removal. Flight schedule modification might involve restricting flights, for example, during a 20-minute period at sunrise and sunset when large



A Brazilian Air Force jet trailing debris and remains immediately after a bird strike in 2007. As many as 92 percent of bird strikes occur low altitudes of 3,000 feet above ground level or below.

flocks of blackbirds move from their daytime feeding site to their nighttime roost. Habitat modification may include food/prey management, vegetation management, water management, and airport building management/modification. Resource protection includes protection of the habitat through proper use of federally regulated pesticides. Repelling/exclusion can include propane cannons, pyrotechnics, distress call tapes, building modification to reduce nesting, and decoys such as kites.

Swallow-tailed kites, for example, are small birds that prey on small lizards, rodents, and birds. The decoys are light and attached to poles via a thin line. The kite decoys are designed to trail out away from the pole in the wind and appear to be in flight and stalking their prey, thus, deterring small birds from the vicinity. Trained falcons and dogs may also be used to repel birds. Removal may include live traps, pesticides, or firearms for overpopulated or difficult-to-control animals.

Patterns

An understanding of migratory bird patterns is an essential part of understanding the bird strike problem. The U.S. Fish and Wildlife Service Migratory Bird Program is the lead federal agency for managing and conserving migratory birds in the United States, and it manages over 1,000 species. One of the areas of responsibility charged under the Migratory Bird Program is Birds of Management Concern.

These include species that are too few or too many, are involved in societal demands, and may conflict with human interests.

Over 34 percent of all bird strikes involve migratory birds. In 1995, a U.S. Air Force Boeing E-3 Sentry aircraft departing Elmendorf Air Force Base near Anchorage, Alaska, encountered a flock of geese, lost two of its four engines due to ingestion, and crashed shortly after, killing all 24 aboard. In January 2009, US Airways Flight 1549, an Airbus A320, encountered a flock of geese shortly after departing LaGuardia Airport in New York City. Flight 1549 lost one engine and partial power in the other due to ingestion but made a water landing in the Hudson River with only two injuries. The Migratory Bird Program works closely with the U.S. Air Force, U.S. Army, U.S. Department of Agriculture, and the U.S. Environmental Protection Agency to address the issue of aircraft wildlife strikes.

Migratory birds in the United States use four primary routes, or flyways. The Migratory Bird Program sponsors the U.S. Flyways Program. The four flyways in the United States are the Atlantic, Mississippi, Central, and Pacific flyways. Each is administered by a council, which is responsible for the cooperation of each state in the flyway and adjoining nations. The councils are responsible for setting the migratory bird policies and contribute to migratory bird research and management throughout the United States, Mexico, and Canada.

Organizations

The Bird Strike Committee USA is a voluntary organization in the United States and serves as a forum for the exchange of information, wildlife strike data, promotion of new technologies, and professionalism in wildlife management programs at airports throughout the United States. It was formed in 1991 as a liaison with other similar organizations that are members of the International Bird Strike Committee. These organizations hold annual meetings and conferences around the world to share knowledge on the subject.

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See Also: Airplane Disasters; Airport Planning; Airports, Environmental Issues and; Federal Aviation Administration.

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Benefit–Cost Analysis of Transportation

Benefit–cost analysis (BCA) is the standard procedure to assess projects and policies in the transport sector. The method involves the identification, measurement, and monetary valuation of all effects of the project. This includes the financial costs of implementation and operation of the project and intangible effects such as travel time benefits and gains, environmental impacts, and changes in accident risk. The project is identified as desirable if aggregate benefits exceed aggregate costs. The values of effects occurring in the future are converted to present values using a discount rate. Although the method provides reliable indicators of the worth of the project, it is often criticized due to its focus on issues of economic efficiency and failure to address other social objectives.

Benefit–cost analysis is the most common method to evaluate the worth of a transport project and to compare alternative projects. Transportation agencies and policy makers in most countries use a version of this method to support decisions. The popularity of the method is explained by its relative simplicity and by its strong links with economic theory. The rationale of BCA is that a project generating net benefits is worth undertaking. This relies on the postulate that a project has social

value if the people who are made better off are able to potentially compensate the people who are worse off and still be better off. The method also presupposes that it is possible to assign a monetary value to all (or at least to the large majority of) benefits and costs of the project. As the evaluation of public projects is based on their effects on the whole society, the method is sometimes referred to as social benefit–cost analysis.

The financial costs of the project are an essential component of the analysis and include the initial costs of construction of transport infrastructure or application of transport policies and the operating costs throughout their lifetime. These costs are assessed through the market value of the resources used (including labor and capital). Changes in vehicle costs (such as fuel and maintenance) can also be valued by referring to the market price of the relevant goods. The estimation of the effects of a project in the consumption of these goods should, however, consider several factors, such as changes in travel patterns following the project.

The assignment of a monetary value to other costs and benefits is less straightforward, as most of them are intangible and not traded in the market. The usual procedure in these cases is to obtain a measure of people's preferences, measured as willingness to pay or accept marginal units of the units of the effects of the project. These preferences can be estimated directly by surveys (stated preference

methods) or by assuming that the market prices of goods and services related to the effects indirectly reveal people's preferences over these effects (revealed preference methods).

The assessment of travel time savings or losses is a component of most BCA in the transportation sector. The usual approach is to estimate average travel times before and after the implementation of the project for several types of individuals, trip purposes, and times of day or week. The changes in travel times are then multiplied by unit monetary values of travel time for each type. These unit values are often predetermined, based on recommendations of previous studies or on official standards. In other cases, values can be linked to wages or to other market prices. The evaluation of the aggregate travel-time benefit or cost also requires a forecast of travel demand after the project or policy is implemented, considering induced and suppressed trips and changes in transport mode, routes, or other choices of the individuals in the transport market.

The assessment and evaluation of the effects of the project are also complex in the case of external costs and benefits, that is, impacts on individuals who are not users of the project. This is the case with environmental impacts, which include local and global air pollution, noise, land use, community severance, and effects on wildlife. The quantification of these impacts is not simple, as the effects are uncertain or depend on many contextual variables (for example, meteorological conditions affecting the dispersion of pollutants). The assignment of a monetary value to the effects also depends on factors such as people's perceptions about the extent of the effects, their impact on human health, and the existence of altruistic preferences toward the effects on other individuals or on nonhuman beings. The monetary valuation of environmental effects is often supported by surveys or by hedonic analyses. In the latter case, it is assumed that the housing market is a proxy for costs such as local environmental pollution. Differentials in local rents or house prices can then be treated as indicators of the price of different levels of local air pollution or noise.

The evaluation of safety issues presents similar problems, as there is a high degree of uncertainty in the effects of projects in risk levels. The monetization of property damages is relatively simple, as they can be linked to a market value. However, the assignment of monetary values to human injuries,

fatalities, and lives lost is controversial, due to the sensitivity of the issue. These values are usually inferred from the costs incurred to prevent accidents or from cost of medical treatment or productivity and income losses following accidents.

The BCA method treats the effects of the project occurring in the future by applying a discount rate that converts them to present value. This approach is based on the hypothesis that a monetary value is worth more in the present than in the future. The choice of the discount rate to use in the assessment of a given project is not consensual. The most common method is to use current interest rates for borrowing money. The analysis also needs to specify the period in the future after which benefits and costs become irrelevant or are impossible to estimate.

Criticisms

The use of BCA in transportation has been subject to criticism because of a perceived failure to address noneconomic concerns and ethical issues. Most of the arguments deal with the fact that by measuring benefits and costs through people's willingness to pay, the welfare of individuals with lower ability to pay is given a lower weight. The use of a single measure to assess projects, based on net benefits, is also criticized because it addresses only objectives of economic efficiency and does not consider other social objectives, such as equity in the distribution of costs and benefits among different individuals or income or ethnic groups. Due to these limitations, in recent years BCA has been increasingly used alongside other methods, the most important of which is multicriteria analysis.

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See Also: Environmental Impacts; Ethical Issues; Multiple Criteria Decision Making/Aiding; Risk Analysis/Assessment; Travel Demand Forecasting.

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Bicycle Commuting

Bicycle commuting is widely regarded as a utilitarian activity and simply a means to get from origin (usually the home) to destination (the workplace) in the least possible time. The commute by bicycle can, however, also provide opportunities for recreation. For example, some cycle commuters may actively seek less direct and more scenic routes so that their journey provides opportunities for pleasure and fitness.

The choice of bicycle for commuting typically depends on distance, terrain, and personal taste. For shorter distances over flatter terrain, utility bicycles with a more upright riding position and which incorporate mudguards, chain-guard, carrier racks, and integrated locks and lights are favored as they allow riders to commute in relative comfort in regular work clothes because of their functionality and more relaxed riding style. These types of bicycles are more common in flatter areas and in countries where functional cycling is more established, such as the Netherlands and Denmark.

For bicycle commutes over longer distances or more varied terrain, hybrid bicycles and mountain bikes with less upright riding positions, a wider range of gearing, and mix of extra components and accessories are commonly used. These types of bicycles are more common in highly motorized economies where commuters typically have to mix and move with the flow of motor traffic.

The bicycle commute can also be integrated with public transport over longer distances. Folding bicycles are gaining popularity because of their portability and because rigid bicycles are typically not permitted aboard public transport vehicles during peak periods. Public bike hire schemes also provide the opportunity for public transport users to use

cycling as an access mode to, or egress mode from, public transport hubs. Fixed-gear and/or single-speed road bikes and other variants have undergone a renaissance in recent years and are used for commuting, particularly among younger riders in some flatter European and North American cities, because of their simplicity and their fashion status.

Personal benefits of bicycle commuting include saving money that would otherwise be spent on fuel or public transport and the opportunity to maintain a healthy lifestyle by incorporating regular exercise into daily travel routines. For companies, it can result in a healthier workforce and less demand for space for car parking. Wider societal and environmental benefits include reduced demands on resources required to operate and maintain a motorized transport system, reduced traffic congestion and associated air pollution, reduced demand for limited space on public transport, improved public health, and improved quality of life and social inclusion in urban areas.

There has been a general decline in the rate of bicycle commuting among countries in western Europe and North America since the advent of mass motorization in the 1950s and 1960s. However, some countries have been successful in reversing this decline and maintaining reasonable levels of cycling within the transport mix. This has been achieved through sustained policy supporting cycling, including containment of urban development to reduce distances between homes and activities (including workplaces), investment in purpose-built cycling infrastructure, restrictions on car use in urban areas, and promotional activities to generate a positive culture toward cycling.

Wide variation in the level of cycle commuting is evident between countries that have traditionally concentrated resources on developing infrastructure for accommodating more motorized travel and those that have attempted to manage motorized travel and that have invested in good-quality cycle infrastructure. For example, in the United States and the United Kingdom, countries that have traditionally neglected cycling, less than 1 percent and 3 percent of all journeys, respectively, are by cycle. This contrasts with 10 percent of all journeys in Germany, 18 percent in Denmark, and 26 percent in the Netherlands. Commuter journeys also represent a much smaller proportion of overall journeys made by bicycle in the United States (15 percent)

compared to recreation (60 percent), whereas in the Netherlands, Denmark, and Germany, and to a less significant extent, the UK, cycling is mainly for practical utilitarian purposes.

Deterrents to cycle commuting include time and inconvenience due to journey distance, difficulty integrating cycling with public transport for longer journeys, lack of real or perceived safe routes between home and the workplace, lack of provision of secure cycle parking facilities at the workplace, complex household travel arrangements, the nature of employment/need to use a vehicle in the course of work, climate and weather, the perceived abnormality of cycling, and the ease and convenience of using other transport options such as the car.

There are general moves by policy makers to encourage bicycle commuting in heavily motorized societies. Municipal highway authorities are being encouraged by government to improve cycle infrastructure and companies are being encouraged to be proactive in supporting their employees' desire to bicycle to work. Measures include provision of secure cycle parking, provision of washing and changing facilities, support for employees purchasing cycles and equipment as salary sacrifice and tax-free benefit, subsidizing regular visits by a "Bicycle Doctor" to carry out maintenance or repairs, and inspiring the workforce to commute by bicycle through promotion and marketing, for example, taking part in annual "Bike to Work" campaigns.

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See Also: Bicycle Facilities; Bicycle Safety; Bicycles; Bicycles, Electric; Bicycle–Transit Linkages; Bicycling, Health and Recreational Aspects of.

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Bicycle Facilities

Bicycle facilities are essential to promote cycling in cities. Dedicated parking for bicycles, changing stations and showers at origins and destinations, as well as wheeling ramps alongside steps, are important complementary cycling infrastructure to cycle tracks, cycle lanes, and traffic calming measures. Bicycle parking should be planned for residential areas and main destinations and transport interchanges. Likewise, it is important to plan facilities for short-stay and long-stay parking, the latter normally requiring some type of weather protection and additional security.

Bicycle Parking

Good bicycle parking is essential to promote cycling. Bicycle parking should be provided at regional destinations, public transport interchanges, local attractors, and residential areas. Two main issues are essential when planning the amount and type of cycle parking: proximity and security. Duration of parking is also important to determine the type of parking supply. By counting the number of bicycles locked to street furniture and to existent cycle parking, it is possible to estimate the amount of unsatisfied demand and increase parking provision. Although there are several types of cycle parking equipment, the Sheffield stand is the most adequate design, as it allows for holding the bicycle and locking both wheels.

Four main approaches to planning bicycle parking can be considered in accordance with the length of stay and the type of user:

- *Mini:* Stands and racks, free and on-street. Designed for short stays and drop-in customers and visitors—up to two hours
- *Midi:* Small-scale, locked and covered facilities. Designed for residents, medium-term parking for visitors and employees—up to eight hours or overnight.

- *Maxi*: Constructed parking for neighborhoods. Designed for residents, should be planned for overnight parking.
- *Mega*: City center parking or at main stations. Designed for city center residents, tourists, employees, etc.

Site Considerations

In order to be effective, bicycle parking should be easy to find and located as close to destinations as possible. Proximity is the key element. It is preferable to have several small clusters of cycle parking spread around the city rather than only a few large parking areas. Nevertheless, normally cyclists are willing to park away from the destination if the parking is designed for a long stay in a high-quality covered and secure parking facility. Parking should also be easy to use and allow locking both wheels of the bicycle without removing the front wheel and to support and lock the bicycle frame. Stands that require the bicycle to be lifted should be avoided.

All high-demand areas such as transport interchanges, tourist places, and other attractors should have cycle parking. This includes workplaces, educational institutions, public transport stations, town centers, shopping centers, entertainment and cultural institutions, stadiums and sports facilities, and recreational destinations such as beaches and parks. Cycle parking use should be monitored in order to increase supply or relocate stands if necessary.

Ideally cycle parking should be free, including cycle lockers and other secure covered parking. If charged, fees should be as affordable as possible. Long-stay parking is as important as short-stay parking, and covered, secure parking should be provided in residential areas, public transport interchanges, and major employment areas.

Types of Parking Facilities

There are five main types of parking facilities:

- *Cycle stands*: Designed for one or two bicycles.
- *Cycle racks*: designed for six or more bicycles.
- *Cycle lockers or boxes*: provide weather protection and added space for storage of helmets, bags, and other accessories; requires a management system and an organization to manage the system.



A serpentine-style bicycle rack in Hillsboro, Oregon, in 2010. This style can accommodate more bicycles than a single Sheffield stand while offering multiple points at which to lock a bicycle.

- *Cycle centers* (guarded cycle parking): collective parking with supervision; offer additional services such as maintenance and repair, bike shop, bike rental, and also may have a small coffee shop.
- *Automatic cycle parking*: bicycle storage facilities in which the cyclist hands in the bicycle at entrance and the system registers and stores the bicycle. The cyclist returns the bicycle with an electronic key.

In residential areas, secure covered parking with restricted access should be provided and could be accommodated within the building, garage, or common area. Additional parking stands for visitors should be provided, being extremely useful in high-density areas and student accommodations. If possible, cycle parking should be located in front of the residences or in the most convenient location in order to reduce travel time by bicycle.

On-street cycle parking should be situated to minimize disturbance to other users of the street, especially pedestrians, and not put cyclists in danger from motor vehicles. There are several cycle stand designs, but the most effective and recommended is

the Sheffield stand. It is an “inverted U” metal tube, set into concrete feet below the surface or bolted to the surface with security locks, allowing two bicycles to stand against it (one on each side) and to lock both wheels of the bicycle without removing the front wheel. Sheffield stands with an additional horizontal crossbar provide extra security and support for small bicycles and are useful as an additional barrier to protect visually impaired people.

Sheffield stands can be installed in a row of three to five stands, creating a cycle rack with capacity to park between eight and 10 bicycles. Small stands that lock only the front wheel are not recommended as they do not allow a secure lock of the bicycle and often create damage to the bicycle itself—these are commonly known as “wheel benders.” Wall loops, wall bars, and locking rings are other easy and affordable solutions that can be provided in places where bicycles are leaned against walls as short-stay parking equipment.

Sheffield stand dimensions are 700–1,000 millimeter (mm) length (800 mm recommended), 750 mm height (+/- 50 mm), tube diameter 50–90 mm (90 mm recommended to increase security of U-locks), corner radii 100–250 mm. Stands should be placed 1,000–1,200 mm apart in order to allow two bicycles to park in each one. A space of 600 mm should be left free between the front of the stand and a wall or curb to accommodate the bicycle. If placed parallel to the wall a minimum space of 900 mm is needed. Stands can be embedded in concrete (250 mm deep) or bolted to the ground.

Cycle lockers provide added weather support and luggage capacity but can be visually intrusive. Therefore, special care regarding the choice of location should be taken when introducing them on streets. There is also the possibility of combining cycle stands or racks with public lockers to store luggage and accessories. Lockers normally require supervision to prevent vandalism but can also be used as advertising space, reducing the operational cost, which is over five times the cost of a Sheffield stand.

Cycle centers can provide space for between 1,000 and 4,000 bicycles and require the payment of a parking charge in exchange for safe and secure cycle parking. These centers normally have other additional services, such as maintenance and repairs, a bike shop selling accessories, bike rental, tourist information, and maybe even a small coffee

shop and/or newsstand to increase viability. In these large parking facilities, designated for long-stay parking, it is common to have two-story parking, which allows doubling the capacity of the parking space. Multistory and automated parking facilities are also efficient ways of enlarging parking capacity within the same space.

Changing Stations and Showers

Providing changing stations and showers at major destinations and especially workplaces can have a significant impact on the choice of the bicycle for daily mobility. By having access to changing stations and showers, employees can freely cycle to work, even making the commute an intensive sporting activity if so wanted, as it is possible to take a shower at the workplace.

If possible, changing stations and showers should be provided with lockers. Lockers allow cyclists to leave shampoo, shower gel, and a towel at the destination, and sometimes even a pair of shoes. Separate facilities should be provided for men and women. The specific amount of space needed will depend of the number of cyclists, but a minimum of two showers and 10 lockers for each station is recommended for a medium-sized company.

It is also possible, although less common, to install public changing stations and showers at major destinations and transport interchanges. In this case, a fee may be charged to use the facility. Alternatively, special agreements with gyms and other sports facilities can be made in order to allow cyclists to use their showers by paying a modest fee or buying a yearly or monthly access card.

Wheeling Ramps

There are several situations in which cyclists use routes previously designed for pedestrians. In these situations there may be footbridges or flights of steps on the way, and cyclists will have to carry their bicycles up or down the steps. In these situations, wheeling ramps should be added to one or even both sides of the steps. These ramps can be either a steel ramp or made of concrete over the steps. Normally a channel 100 mm wide and 50 mm deep is adequate. If made of steel, they should have a non-slip surface to create some traction for the descent.

Wheeling ramps are typically installed on the right side of the steps and can be located either close to a wall or at sufficient distance to allow pedals

and handlebars not to crash into the wall with the bike in a vertical position. In either case, pedestrian movements should not be obstructed by the ramp.

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See Also: Bicycle Commuting; Bicycles; Bicycle–Transit Linkages; Bikeways/Bike Lanes, Road Design Issues of; Traffic Calming.

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Bicycle Safety

Bicycle safety is a very broad topic. This article focuses on collisions between bicycles and either pedestrians or automobiles. A collision is an impact caused by two or more moving vehicles or bodies coming into contact and exerting force upon each other; whereas, a crash is when a bicycle rider loses control and impacts a stationary object or falls from the bicycle. A collision is a type of a crash but not all crashes are collisions. Moreover, it is important to note that pedestrian and automobile/bike collisions are a small subset of all bicycle crashes, but they are significant from a policy standpoint due to the possible impact on traffic flow and the high potential for serious injury. In all 50 U.S. states and the District of Columbia, bicycles are either (1) defined as vehicles or (2) granted all the general rights and duties of drivers of vehicles when they are traveling on roadways. Many states, counties, and jurisdictions have an additional section in the

legal code regarding additional rights and responsibilities for bicycle riders. In places where bicycle riders may ride on the sidewalk, they typically have the rights and duties of pedestrians. It is best for bicycle riders to learn the relevant legal codes where they ride.

Limitations of Data Collection

Data on bicycle crashes are limited, but existing statistics show that more than half, and possibly the vast majority, of all bicycle crashes are caused by a bicycle rider losing control of the bicycle and falling or crashing into an object. Among capable adult bicycle riders, about 10–15 percent of reported bicycle crashes are collisions with motor vehicles. In these reported collisions with motor vehicles, the bicycle rider was at fault about half the time and the motorist was at fault about half the time.

The primary reason for the lack of good data is that most bicycle crashes and many collisions are never reported, especially minor falls that lead to minimal injuries, which are rather commonplace. Many bicycle–motor vehicle collisions are not well documented or reported. First responders do not consistently log bicycle collisions and hospital and police records are not consistently good. Near misses are not reported or studied carefully, which would be helpful in understanding automobile/bike collisions. The probability of being in a fatal bicycle collision or crash is very low, with a fatality rate of one for every million hours of riding, and the probability of being seriously injured in a bicycle crash or collision is several hundred times more likely than being killed.

Some Trends in the Existing Data

Many or most bicycle crashes are caused by a rider losing control of his/her bicycle and crashing; depending on the population studied, 50–80 percent of incidents are falls or lone crashes rather than collisions. In studies of self-reported accidents of experienced adult bicycle riders, about half of all crashes were lone rider falls or crashes. Among all bicycle riders, including children and the inexperienced, the reported figure is more than 80 percent. These crashes were typically caused by encounters with road hazards, including rail tracks, expansion joints, storm grates, and damaged pavement.

Among experienced adult bicycle riders, about one-third of crashes involved other bikes or



Bicyclists wearing safety helmets ride bikes from a bike-share program on a scenic pathway. Helmets, along with gloves and eye protection, are important passive safety measures. Active safety measures include maintaining control over the bicycle, following the rules of the road and being familiar with traffic law, using good lane positioning, and watching for and avoiding other drivers' mistakes.

nonmotorized vehicles, pedestrians, or animals. Only about 15 percent of the crashes in these studies were collisions between a bicycle and a motor vehicle. This is encouraging for all bicycle riders in that the bicycle rider has the power to reduce the likelihood of crashing by improving bike-handling skills and by maintaining control of his/her bike by slowing down and avoiding risky situations. While it is best to educate and train all bicyclists, the greatest opportunity for safety improvements lies in educating the young and inexperienced.

Some useful generalizations may be made from the statistics that are available, and there is some value in comparing statistics on documented automobile/bike collisions with bicyclist fatalities in regard to assessing the relative severity of hazards under various conditions. It can also be helpful to compare statistics for the general public with those for experienced adult bicycle riders.

Alcohol is a factor in about one-third of automobile/bike collisions on the part of either the motorist or the bike rider. In about one-third of bicyclist fatalities, alcohol is a factor on the part of the bicyclist.

About two-thirds of injury-producing automobile/bike collisions occur in intersections or from cross traffic and about one-third of all fatal collisions involving a bicyclist occur in intersections. The statistics suggest that parallel path collisions are more severe and lead to fatality more often than cross-traffic collisions.

About two-thirds of collisions between bicycles and motor vehicles occur in urban areas, which is generally consistent with population density and ridership patterns. Similarly, the proportion of fatal automobile/bike collisions is about two-thirds in urban areas. Automobile/bike collisions do tend to be more severe in rural areas, although fatality rates are similar between urban and rural areas. This

is attributed to the different road conditions and driver and bicycle rider behaviors in these areas.

There are notable patterns of injury and fatality that vary by age and sex of the bicycle rider. Males of all ages are much more likely to be injured or killed while bicycling than females. The injury and fatality rates for children are much higher than for adults in automobile/bike collisions, especially the 10 to 15 year age group. Compared to adults, children involved in automobile/bike collisions are also about twice as likely to be at fault. Although it is difficult to establish causality, there is a correlation between increases in bicycle traffic and improved road safety for all users.

Impact Speed and Severity of Injury

The speed of an object at the moment of impact is one of the primary variables in how much force is applied upon impact. Studies of automobile/pedestrian collisions consistently reveal that pedestrian injury and death rates increase at higher impact speeds. Not only are fast-moving vehicles a potential threat to those around them, there is also a nonlinear increase in the risk of injury or death at increased speeds.

Effects of Changing Technology

Electric and hybrid cars present special threats to bicycle riders because they are so much quieter than automobiles powered solely by internal combustion engines. Bicycle riders rely heavily on their hearing, and the lack of engine noise of hybrid and electric cars makes it more difficult for bicycle riders to hear an approaching vehicle. Collision rates between hybrid cars and bikes have been observed to be higher than between bikes and internal combustion engines cars.

Methods to Reduce Crashes and Collisions and Mitigate Negative Outcomes

There are design and engineering approaches that use technical methods and there are social approaches and methods for improving safety. There are also plural and hybrid approaches that employ technical and social strategies. Driver and bicycle rider education, better enforcement, and better roadway design have great potential for improving road safety.

Even experienced bike riders can benefit from taking a bicycle safety course. At present there are

many bicycle safety education programs in all parts of the country. There is a nationwide movement called Safe Routes to School that educates and encourages elementary and middle school students to bicycle and walk safely. The League of American Bicyclists runs a nationwide Smart Cycling program that trains instructors and teaches Traffic Skills 101 and other courses. Local bike clubs often offer these courses or variations of Traffic Skills 101. There are also other bike safety educator training programs.

For best safety, bicycle riders should employ both active and passive safety measures. Active safety measures are techniques of active engagement with the vehicular environment on behalf of safety. The core principles of crash prevention while riding a bicycle include: control your bicycle, follow the rules of the road and be familiar with traffic law, use good lane positioning, learn to watch for and avoid other drivers' mistakes. Passive safety measures include using protective equipment such as helmets, gloves, and eye protection. While bicycling, it is important to wear a properly sized and fitted Consumer Product Safety Commission (CPSC) certified helmet. More effective education and law enforcement related to speeding and aggressive and distracted driving can also be especially effective for improving road safety for bicycle riders.

As an individual bicycle rider, safety depends directly on the mechanical integrity of the bicycle. It is best to know how to assess the condition and adjustments of one's own bicycle. If one cannot confidently do this, it is best to seek professional help at a reputable bicycle repair shop. Introductory bicycle safety and mechanics classes are available in many locations and interested parties may seek informal instruction from their local bicycle mechanic. In addition to the safe mechanical functioning of a bicycle, equipment may be legally regulated. Front lights and rear reflectors are typically required at night, and in many locations bikes are required to have brakes that can skid the wheel.

Fundamental bicycle handling skills include starting, stopping, shifting, braking, steering, straight-line riding, scanning, signaling, and performing evasive maneuvers. Three commonly taught evasive maneuvers that nearly any bike rider can readily learn are the "quick stop," the "rock dodge," and the "quick turn." These skills are generally taught as part of the core curriculum in applied bicycle safety

courses for adults. Collisions between bicycles and motor vehicles can be reduced and mitigated by better use of active and passive safety measures, improved roadway design, education, and enforcement for all road users.

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See Also: Bicycle Commuting; Bicycle Facilities; Bikeways/Bike Lanes, Road Design Issues of; Nonmotorized Vehicles, Safety Issues of.

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the last location of a nearby bike sharing bicycle. Bicycle sharing provides a variety of pickup and drop-off locations, enabling an on-demand, very-low-emission form of mobility. The majority of bike sharing programs cover the cost of bicycle maintenance, storage, and parking (similar to car sharing or short-term auto access). Trips can be point-to-point, round-trip, or both, allowing the bicycles to be used for one-way transport and for multimodal connectivity (first-and-last-mile trips, many-mile trips, or both). Generally, trips of less than 30 minutes are free. Users join the bike sharing organization on an annual, monthly, daily, or per-trip basis. Members can pick up a bike at any dock by using their credit card, membership card, key, and/or a mobile phone. When they finish using the bike, they can return it to any dock (or the same dock in a round-trip service) where there is room and end their session.

By addressing the storage, maintenance, and parking aspects of bicycle ownership, public bike sharing encourages cycling among users who may not otherwise use bicycles. Additionally, the availability of a large number of bicycles in multiple dense, nearby locations frequently creates a "network effect," further encouraging cycling and, more specifically, the use of public bike sharing for regular trips (for example, commuting, errands).

Public Bike Sharing Generations

Over the past five decades, public bike sharing has been categorized into four key phases or generations:

- *First generation:* "White bikes" (free bikes)
- *Second generation:* Coin-deposit systems
- *Third generation:* IT-based systems
- *Fourth generation:* Demand-responsive, multimodal systems (or the next generation of IT-based bike sharing).

First generation: "White bikes." Bicycles are typically painted one color, left unlocked, and placed randomly throughout an area for free use. First-generation systems do not use docking ports. In some of the systems, the bikes are locked; users must get a key from a participating local business and may also be required to leave a credit card deposit, but the actual bike use is free. Many first-generation systems eventually ceased operations due to theft and bicycle vandalism, but some are still operating as

Bicycle Sharing

In a public bicycle sharing system, users access bicycles on an as-needed basis. Information technology (or IT)-based bike sharing can be facilitated through a network of stations (typically unattended) or through dockless bike sharing, where riders use their mobile electronic devices to determine

community-based initiatives. The earliest of these first-generation programs was the Provos' White Bike plan, which began operation in July 1965 in Amsterdam. The first North American program, called the Yellow Bike Project, was launched in 1994 in Portland, Oregon, and operated until 2001. The Green Bike Program in Boulder, Colorado, followed this in 1995. Both of these systems eventually stopped operating because of bicycle theft.

Second generation: Coin-deposit systems. In a coin-deposit system, bicycles have designated docking stations/parking locations where they are locked, borrowed, and returned. A deposit, generally not more than \$4, is required to unlock a bike. Although coin-deposit systems helped reduce theft and vandalism, the problem was not eliminated, in part because of user anonymity. Many second-generation systems are still in operation. The first system, Bicyklen, was deployed in Copenhagen, Denmark, in 1995. The Twin Cities (Minneapolis and St. Paul, Minnesota) also launched a second-generation system in 1995 called the Yellow Bike Program. A number of other coin-deposit bicycle sharing programs were launched throughout the United States (for example, in Austin, Texas; Decatur, Georgia; and Princeton, New Jersey). Community-based first- and second-generation bike sharing systems are still operating in the United States.

Third generation: IT-based systems. IT-based systems use electronic and wireless communications for bicycle pickup, drop-off, and tracking. User accountability has been improved through the use of credit or debit cards. Third-generation bike sharing includes docking stations, kiosks, or user interface technology for check-in and check-out, and advanced technology (for example, magnetic-strip cards, smartcards, smart keys). Although these systems are more expensive than first- or second-generation systems, information technology enables public bike sharing programs to track bicycles and access user information, improves system management, and deters bike theft. IT-based systems are responsible for public bicycle sharing's recent expansion in both locations and scale.

The first IT-based system, called Smart Bike (also known as Vélo à la Carte), launched in Rennes, France, in 1998. Clear Channel Communications, Inc., managed this program. It ceased operation in



Bicycles from the SEVici bike share in Seville, Spain, in 2010. Seville's bike share launched in 2007 and was modeled on a program in Lyon, France. As with other third-generation bike-share programs, it is an IT-based system using smartcards.

2009 when the contract expired, and was replaced by LE Vélo STAR. The first IT-based program to launch in Asia was Smart Bike (later renamed TownBike) in Singapore. It operated from 1999 to 2007. North America's first IT-based system, Tulsa Townies, started operating in 2007 in Tulsa, Oklahoma. This was the first solar-powered, fully automated docking-based system in the world. In Canada, the first IT-based system, BIXI (Bicycle-TaXI), began operating in 2009 in Montreal. Since then, BIXI has expanded to Ottawa and Toronto. In February 2010, Mexico City launched EcoBici.

Fourth generation: Demand-responsive, multimodal systems. Demand-responsive, multimodal systems build upon the technology of third-generation

Table 1 Public bike sharing business models

Business Model	Definition	Example (as of May 2013)
Non-Profit	• Goal of covering operational costs and expanding service • Start-up and operational funding typically are supported by grants, sponsorships, and loans	Denver B-cycle Denver, CO (Operational)
Privately Owned and Operated	• Owned and operated by a private entity • Operator provides all funding for equipment and operations • May have limited contractual agreement with public entities for rights-of-way	DecoBike Miami, FL (Operational)
Publicly Owned and Operated	• Owned and operated by a public agency or local government • Agency subsidizes bikesharing with system revenue	Golden Community Bike Share Golden, BC (Suspended)
Publicly Owned/ Contractor Operated	• Owned by a public agency or local government, responsible for funding and administering the system • Operations are contracted to a private operator	Capital Bikeshare Washington, D.C. (Operational)
Street Furniture Contract	• Operator permitted to operate in a jurisdiction in exchange for advertising rights, generally with street furniture • System funded through advertising revenue	SmartBike D.C. Washington, D.C. (Defunct)
Third-Party Operated	• Operated in partnership with local businesses in exchange for a percentage of the profit • Hybrid operation scheme that can be paired with other business model	Chicago B-cycle Chicago, IL (Defunct)
Vendor Operated	• Operated by the same company that designs and/or manufactures the system equipment (the vendor)	Bike Nation Anaheim Anaheim, CA (Operational)

Source: Shaheen, Susan, Adam Cohen, and Elliot Martin. "Public Bikesharing in North America: Early Operator Understanding and Emerging Trends." *Transportation Research Record*, no.2387 (2013).

systems by implementing enhanced features such as flexible, clean docking stations or "dockless" bicycles; demand-responsive bicycle redistribution innovations to facilitate system rebalancing; value pricing to encourage self-rebalancing; multimodal access; billing integration (for example, sharing smartcards with public transit and car sharing); real-time transit integration and system data dashboards; and Global Positioning System (GPS) tracking.

Business Models

A number of public bicycle sharing business models have evolved with the advent of IT-based systems,

including (1) nonprofit, (2) privately owned and operated, (3) publicly owned and operated, (4) publicly owned/contractor operated, (5) street-furniture contract, (6) third-party operated, and (7) vendor operated. Due to variations in ownership, system administration, and operations, there can be overlap between these models. A description of these models is included in Table 1.

Public Bike Sharing Impacts

Public bike sharing offers a number of environmental, social, and transportation-related benefits. Potential bicycle sharing benefits include

(1) increased mobility, (2) economic benefits (including cost savings from modal shifts and increased tourism), (3) lower implementation and operational costs (in contrast to shuttle services), (4) reduced traffic congestion, (5) reduced emissions and fuel use, (6) increased public transit use, (7) increased health benefits, and (8) greater environmental awareness.

An early member survey of four public bike sharing programs in North America was conducted from November 2011 to January 2012, including Montreal, the Twin Cities (Minneapolis and Saint Paul), Toronto, and Washington, D.C. The survey was administered online for all programs and surveyed both annual and 30-day subscribers. Of the total 10,661 respondents, 6,486 came from the United States and 4,175 came from Canada. The survey probed user perceptions about bike sharing and found that a majority in the surveyed cities felt that bicycle sharing was an enhancement to public transportation and improved transit connectivity. In all cities, bike sharing resulted in a considerable decline in personal driving and taxi use, suggesting that bike sharing is reducing urban transportation emissions, while at the same time freeing capacity of bus and rail networks within large cities.

North American Helmet Use and Crash Rates

Public bicycle sharing experts and users generally perceive helmet laws as an obstacle to bike sharing use because of the inconvenience associated with carrying a helmet, lack of availability for last-minute trips, and the challenges associated with providing sterile shared-use helmets. Some organizations located in jurisdictions with compulsory helmet laws offer complimentary helmets with each bike rental. Other operators sell helmets or offer them through partnerships with local bike stores to provide discounts.

The 2011–12 North American user survey of four public bicycle sharing programs, discussed above, found that the majority of respondents never wear helmets. In Montreal, 62 percent of survey respondents indicated never wearing a helmet while bike sharing, compared to 50 percent in the Twin Cities, 45 percent in Toronto, and 43 percent in Washington, D.C. The survey also found that helmet use ranged between 20 percent and 38 percent while using bike sharing.

In the same North American study of all 19 IT-based public bike sharing programs, researchers

found that operators with more than 1,000 bicycles reported an average of 4.33 crashes per year, those with between 250 and 1,000 bicycles averaged 0.6 reported crashes a year, and those with fewer than 250 bikes reported 0.3 crashes per year. Despite more limited helmet use, the accident or crash rate for public bicycle sharing was quite low in North America, as reported in 2011.

In Vancouver, British Columbia, Canada, three private companies are developing options for providing sterile shared helmets, including a helmet-rental sanitizing machine (for example, SandVault's HelmetStation, a fully integrated helmet-dispensing system that sanitizes the helmets upon return) and disposable helmets.

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See Also; Bicycle Safety; Bicycles; Bicycle–Transit Linkages; Bikeways/Bike Lanes, Road Design Issues of; Car Sharing; Green Transportation.

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Bicycles

A timely global trend is the increase in the use of bicycles for commuting purposes. While in many parts of the world bikes are—and have been—used as a necessary component of transportation, it is only recently that their use in industrialized countries is being seen as an attractive alternative to fossil-fuel-burning vehicles. Present roadway infrastructure in many urban areas is not appropriately developed in relation to the needs of cycle commuters. Data show that in the United States more than 40 percent of the trips people take with cars are less than two miles, a distance that could easily be managed on a bicycle by most people with some planning and appropriate bikeways.

Bicycle Commuting

Commuting by bicycle is becoming more desirable as the total benefits are becoming more evident. Not only is cycling beneficial to the environment by reducing air pollution, carbon emissions, and traffic congestion, but it is also a healthy alternative as it increases physical activity, improves cardiovascular health, and reduces obesity rates in communities. As a viable commuting option, cycling also saves individuals the expense for daily travel that might otherwise be spent on fuel. City leaders are finding that planning for more bike travel increases the quality of life in neighborhoods and communities.

Innovations in cycling infrastructure, transportation policies, financial incentives, and zoning laws are being applied in more and more cities, most notably in Europe but also in the United States, Colombia, Australia, and China. In industrialized countries where pro-cycling planning and policies are in place, bicycle commuter rates are highest; the Netherlands, Denmark, and Germany (among

other northern European nations) can claim rates of 20 to 30 percent in urban commutes. For China, once called the “Bicycle Kingdom,” bicycles play a very important cultural role. (During the 1960s and 1970s a bike was considered one the three most important and valuable assets that a family could own.) With increased industrialization and production of cars in China, official planning policies often favor cars, and newer transportation infrastructure often excludes bicycles. Still, many Chinese cities have very high cycling rates by world standards.

Compared to other parts of the industrialized world, bicycle commuting rates in the United States are low—the national average is under 2 percent. However, this transportation trend is gaining momentum. As of 2011, the U.S. cities with the highest (top five) bicycle commuting rates are Davis, California (22.1 percent), Boulder, Colorado (9.9 percent), Eugene, Oregon (8.3 percent), Berkeley, California (8 percent), and Cambridge, Massachusetts (6.8 percent). Large U.S. cities with the (top five) highest rates are Portland, Oregon (6 percent), Seattle, Washington (3.6 percent), San Francisco, California (3.5 percent), Minneapolis, Minnesota (3.5 percent), and Washington, D.C. (3.1 percent). What is promising is that, according to the U.S. Census Bureau’s American Community Survey, from 2000 to 2011, 39 bicycle friendly communities (BFCs) among the 70 largest U.S. cities saw an 80 percent increase in bicycle commuting.



Cycle rickshaws are a type of tricycle, powered by pedaling, and designed to carry passengers on a for-hire basis. They are widely used in cities around the world, most commonly in east Asia.

Infrastructure

Researchers and urban planners are finding that increasing the amount and quality of bicycling infrastructure is key to encouraging bike use for travel to work, to school, or shopping. Some studies have been done to assess the effectiveness of various strategies for increasing the use of bicycles. These include providing on-street bike lanes, off-street bike paths, bicycle boulevards, rails-to-trails, and other bicycling infrastructure, such as speed humps, curb extensions, pedestrian crossways, and cycle tracks, which are on-street bike lanes that are physically separated from motor vehicle lanes. New forms of road markings, such as bike boxes, shared lane markings, and colored bike lanes with graphics and signs, may also encourage bike travel.

Promotional and educational programs, along with municipal marketing programs such as bike-to-work days, BFCs, Safe Routes to School programs, and bicycle training classes have become popular in some urban areas. Additional policies, including parking restrictions, traffic-calmed neighborhoods, parking for bicycles, and accommodations on buses and trains for bikes may all, collectively, encourage cycle commuting.

Bike Sharing

Larger cities may benefit from bike-sharing programs. In 2010, Washington, D.C., together with Arlington, Virginia, launched Capital Bikeshare, a regional program. In September 2011, on the first anniversary of its launch, the city also celebrated its 1-millionth-rider milestone. (It hit 4 million riders in May 2013.) Both Washington, D.C.'s bike share program and New York City's new (as of May 2013) Citi Bike sharing program offer bicycles for citizens to "share" or borrow; the first 30 minutes of each trip are free. Pickup and parking kiosks can be accessed in various locations around the cities, usually within close range of transit rides.

"Third-generation" bike sharing technology implements security solutions, including electronically locking racks or bike locks, chip cards, mobile phones, and Internet, meaning bike users are identified and bikes are more secure. During 2010, four major American cities opened third-generation bike sharing programs: Denver, Colorado, with 500 bikes and 50 stations; Minneapolis, Minnesota, with 700 bikes and 65 stations; Chicago, Illinois, with 100 bikes and 6 stations; and Washington, D.C., with

1,100 bikes and 110 stations. Other major cities and urban areas in the United States are following suit; and some have already experienced great success. A great example of progress in a densely urban area is New York City.

New York City

In 2009, New York City's Department of Transportation (NYDOT) initiated an effort to upgrade cycling infrastructure. More than 50 acres of road space in the city has since been converted from traffic lanes and parking lots to more than 200 miles (320 kilometers) of new bike lanes. NYDOT's strategic plan laid out the accelerated goal of doubling bicycle commuting between 2007 and 2012 and tripling it by 2017. The city reached the goal of doubling bicycle commuting in 2011, a year early. Another goal is to reach 1,800 miles (2,900 kilometers) of city bike lanes in the next 20 years, establishing about 50 miles (80 kilometers) of new lanes per year.

Conclusion

Cities that can expand their bikeways, along with other elements of cycling infrastructure, have a better chance of realizing such a goal. The strategies and policies needed to increase bicycle commuting have been successfully tested over time in many European cities. Communities that implement a more integrated system of strategies tend to be more successful. Along with the added miles of bike lanes and bike paths, there needs to be a comprehensive plan in place, including safety measures, easy bike-to-transit locations, bikes to be rented or shared, cooperation with workplaces and schools (such as showering facilities), and eventually, whole neighborhoods and communities that have more accommodating mixed land-use policies. This means designing communities that incorporate commercial, municipal, and public areas in such a way as to de-emphasize the need for motorized vehicles, and to make walking or cycling a more attractive option.

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See Also: Air Pollution/Air Quality; Bicycle Commuting; Bicycle Facilities; Bicycle Safety; Bicycle Sharing; Bicycle-Transit Linkages; Bikeways/Bike Lanes, Road Design Issues of; Green Transportation;

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Bicycles, Electric

While electric cars have captured a lot of attention, electric bicycles are proving to be a dynamic, fast-growing sector of the electric vehicle market. Electric bicycles come in two varieties: powered bicycles (PBs) and power-assisted bicycles (PABs). On PBs, the electric motor operates with a throttle or switch and so provides power assistance without any pedal action. On PABs the power assistance is only provided when the rider is pedaling. Some PABs have a sensor in the crank that matches the power assistance to the needs of the rider (maximum power when needed most, like going uphill, and no additional power when it is not needed anyway, like going downhill). The provision of power assistance reduces or eliminates a number of key barriers to conventional cycling and dramatically increases the accessibility of cycling to a broader range of users.

Market estimates are that global electric bicycle sales were on the order of 24 million units in 2010, with about 90 percent of them sold in China. The

fact that some Chinese cities banned motor scooters and motorcycles powered with internal combustion engines has been a boon for the local electric bicycle industry. However, improvements in technology and design are contributing to growing sales in many countries around the world. Sales elsewhere have been slower, but in Europe sales more than doubled from 2008 (300,000) to 2010 (700,000). Continuous improvements in the technology, particularly battery weight and capacity, along with increasingly stylish designs are likely to contribute to ongoing, if not accelerated, uptake.

Benefits

A number of key barriers to cycling are reduced or eliminated by an electric bike, while many of the benefits of cycling are maintained. Typical barriers created by hilly terrain or lack of fitness are minimized as the rider is required to exert less effort for the same output compared to a pedal bicycle. Less effort also reduces the need to wear cycling-specific clothing or shower at the end of a trip, removing further disincentives. Mode shift options provide significant benefits. People who shift trips from cars to electric bikes report economic savings, reduced gas and parking costs, release from peak travel time traffic congestion, as well as environmental benefits related to reduced private car trips. People who shift from public transport to electric bike, particularly for their commute, report relief from crowded or unreliable services and a sense of freedom and independence.

Significant increases in cycling participation can be achieved with electric bikes as the power assist extends the opportunity to cycle beyond the physically fit. Arguably, the greatest gain is for people for whom riding a conventional bicycle is no longer viable. People who have health conditions that preclude cycling are able to enjoy riding on an electric bike, as are people recovering from injury, surgery, or illness.

Riding sooner and with reduced physical exertion can also help people to benefit from the low-impact exercise and achieve the rehabilitative benefits of cycling. Further, when people actually do pedal their electric bike, there is some level of physical health benefit to be gained. People who are overweight or unfit are able to begin their cycling experience at a gentler pace that may enable them to eventually use a pedal bicycle.

Public Policy

Innovative personal mobility options like electric bicycles have a potentially valuable role to play in advancing the sustainability of our urban transportation systems. However, their integration requires careful weighing of the risks and opportunities they provide in terms of safety, system efficiency, mobility enhancement, energy consumption, and environmental impacts. From a public policy perspective, electric bicycles tend to get little attention because in many jurisdictions they are classified as (conventional) bicycles. Yet, the regulations governing these vehicles vary around the world, and even from state to state within the United States. One crucial feature is the maximum power assistance provided by the electric motor that varies from 250 W in some countries (Australia, Europe, Japan) to 750 (United States). Some regulations prohibit PBs, while others specify a maximum speed (usually about 30 kph) at which power assistance must cut off.

A Caution

The impact of electric bicycles on levels of physical activity requires more investigation. In countries where the existing rate of pedal bicycle use is high, there are some concerns that widespread use of electric bikes may negatively impact people's health. For example, in the Netherlands, where almost 40 percent of trips up to 4.5 kilometers are currently made by bicycle, a mode shift from conventional bicycle to electric bicycle may consequently reduce an individual's overall health. It is not yet known if this concern will be realized. It is possible that electric bikes may extend someone's riding life and provide additional benefits in terms of increasing active transport options and the benefits of maintaining independent travel.

However, in countries with low rates of cycling participation, including the United States, United Kingdom, and Australia, it is more likely that an electric bike will offer a transport mode that will encourage more people to ride. Given the low proportion of people who cycle in these countries, the mode shift is likely to be from cars and public transport to electric bikes and this could result in substantial personal and community benefits.

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See Also: Bicycle Commuting; Bicycles; Bicycling, Health and Recreational Aspects of; Bikeways/Bike Lanes, Road Design Issues of.

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Bicycle–Transit Linkages

Cycling and transit both contribute to improved health and environmental outcomes, as well as to reduce energy use and traffic congestion. Bicycle–transit linkages can help replace driving to and

from stations, expand transit's catchment area beyond walking distance, reduce the need to transfer among transit services, and attract both existing and new transit users. Bike-and-ride provisions are less expensive and more sustainable and socially equitable than park-and-ride facilities for cars. Coordination of cycling and transit includes bike parking at stations and transit stops, on-board space for transporting bicycles with travelers, bike rental facilities near transit stations, "complete streets" policies that promote bike routes near public transportation, partnerships that pursue cross-promotion of cycling and transit, and complementary car parking regulations and fees that limit space for automobiles at transit stations and create disincentives for driving.

Strategies to integrate cycling and transit vary globally, and implementation efforts generally have been increasing in recent decades. Coordination efforts in Europe and Japan began much earlier than in North America, reflecting differences in the overall levels of travel by bicycle and transit. There are currently an estimated 800,000 bike parking spaces at metro and suburban rail stations in Tokyo, where 20 percent of transit passengers cycle to stations, and 325,000 bike parking spaces at train stations in the Netherlands, where 39 percent of all rail passengers cycle to stations. In contrast, the entire United States has an estimated 38,000 bike-and-ride parking spaces, and just 3 percent of passengers currently access transit by bicycle.

Implementation of the integration strategies also varies geographically. For example, Japan and Europe have tended to focus on the provision of facilities at transit stations (bike-to-transit), which faces fewer capacity constraints, while North American efforts have prioritized onboard accommodations (bike-on-transit), which North American passengers prefer over leaving bikes at stations. Bike route networks are better connected to transit stations in Europe than in North America, where bike paths are more recreationally oriented along rivers and through parks. In general, the demand for bike-and-ride provisions continues to grow globally, and cities around the world are devoting more resources for both existing and new innovative approaches to support the integration of cycling and transit.

A range of cycling–transit integration strategies have been developed in recent decades. All of the strategies discussed below have been found to be

effective at increasing bike-and-ride travel as well as overall cycling and transit levels.

Facilities

The most common cycling–transit integration strategy globally is the provision of bike parking at transit stations. With this strategy, travelers leave their bicycles at the access station and rely on another bicycle or mode of transportation (often walking) at the egress station. In general, bike parking costs less than a tenth as much as park-and-ride facilities for automobiles on a per-passenger basis. There are many different types of bike parking, ranging from simple bike racks near bus stops to full-service bike stations, which are often located near major rail terminals. The degree to which bike parking is enclosed is a key distinction and relates to both sheltering from weather as well as security and theft prevention. The continuum ranges from open-air bike parking on sidewalks to guarded parking lots, bike cages and lockers, and full-service indoor bike stations. Open-air bike parking on sidewalks is the least secure and most exposed. Guarded bike parking lots deter theft but offer no protection from the weather.

Bike cages are typically unguarded restricted-access facilities and are often enclosed and incorporate surveillance cameras. They can be less secure than bike lockers, because anyone with access to the facility has access to all the bikes parked there. Boston, Massachusetts, and Portland, Oregon, are two U.S. cities that have deployed this strategy extensively. Many European and some Australian cities also have bike cages at transit stations.

Bike lockers are sturdy boxes that hold one or two bikes and are rented for hourly, daily, or long-term use. They provide more protection from weather and theft than open-air bike parking and bike cages but require more space and resources to construct and manage. Bike lockers in general are the most common form of secure bike parking in North America.

Bike stations offer the most secure and advanced bike parking at transit stations, with the greatest shelter from weather and mitigation of theft risk. They are staffed facilities offering a range of services, such as bike repairs and rentals, showers, and lockers, in addition to secure bike parking. In 2011, the Netherlands had 98 bike stations with space for 85,000 bikes, and Germany had 106 stations offering 32,000 spaces. North American cities with bike stations at



A bicycle commuter in Auckland, New Zealand, takes advantage of on-board bicycle storage to ride a small ferry in 2006. Facilities that make bicycle–transit linkages easier are more developed in parts of Asia and Europe than they are in North America. There are 800,000 bike-and-ride parking spaces alone in Tokyo, Japan, compared to only 38,000 in the entire United States.

that time included San Francisco, Washington, D.C., Toronto, Chicago, Minneapolis, Portland, and Seattle. Tokyo has advanced bike stations that allow the rapid automatic deposit and retrieval of bikes.

Provisions to take bikes onboard transit vehicles are typically in the form of front-end racks for buses, and racks, hooks or delineated spaces on trains. This strategy can reduce concerns about theft and weather exposure related to bike parking at transit stations, though onboard accommodations face more acute capacity constraints—bicyclists may be unable to board a bus with full bike racks or a train full of passengers or other bicycles. The paradoxical result is that onboard accommodations may be most constrained where cycling and transit are most popular. In general, bike racks are common in North America (with over 70 percent of American and 80 percent of Canadian buses equipped) and rare in Europe. Bicycles are typically permitted on

trains in Europe, North America, and Australia outside of peak travel hours.

Bike Rentals and Sharing

Bicycle rental programs at transit stations address many of the limitations of bike parking and onboard accommodations by enabling access to bicycles at both ends of a transit trip, reducing concerns about theft and weather exposure for personal bicycles parked at transit stations, and potentially rendering fewer bike-on-transit trips necessary. Three types of bicycle rental systems have been developed: (1) traditional single hourly or daily rentals requiring a transaction with an attendant, (2) automated hourly or daily rentals based on global positioning system (GPS) technology or membership cards, and (3) public bike sharing systems offering daily or long-term membership and providing access to a network of bicycles.

Bicycle rentals are most widely deployed in Europe, and traditional bike rentals are available at virtually all major Dutch, Danish, German, and Swiss train stations. In addition, several European countries have been leading innovators in the development of public bicycle-sharing systems. Bicycle sharing has evolved in recent decades from “White Bikes” (or “free bikes”) and coin-deposit systems to the information technology-based systems rapidly being deployed around the world today. Typically, bike-sharing fee structures encourage short trips of a half hour or less, and the systems are commonly designed to facilitate “first-mile/last-mile” connections with transit. There are currently approximately 140 public bike-sharing programs in 160 cities with more than 236,000 bicycles around the world.

Bikeways and Bike Lanes

Policies to coordinate bike paths and lanes with the location of transit stations and the operations of transit vehicles are critical for enabling travelers to access transit via cycling and interact with transit vehicles while cycling on the road. “Complete streets” policies have become important for designing streets that facilitate use by transit vehicles and cyclists, as well as automobiles. Cycling paths and lanes close to transit enable cyclists to use transit for planned trips, as well as trips arising from unexpected issues such as mechanical problems and inclement weather. In Europe, cycling networks are typically dense and focused on utilitarian destinations, thereby facilitating cycling for everyday travel needs. In contrast, coordination of paths and lanes in North America has been much more limited and routing has been more focused on recreational cycling.

Other Approaches

Partnerships that facilitate the cross-promotion of cycling and transit can include transit agencies and local jurisdictions, as well as bicycle and environmental advocacy organizations, and may be short-term or long-term collaborations. In North America, where both cycling and transit face less cultural acceptance and more social stigma and opposition, efforts to cross-promote both modes may be more effective at improving the public image of cycling and transit than individual efforts.

Deployment of complementary car parking regulations, fees, and policies is important as well. In

Europe, driver licensure is more expensive, gasoline taxes are higher, and free parking lots at transit stations are less common than in North America. When driving to transit stations is convenient and inexpensive, efforts to encourage travelers to access transit by cycling are less effective. Policies that limit the availability of car parking and charge fees for it at transit stations are important for effectively promoting cycling to transit.

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See Also: Bicycle Commuting; Bicycle Facilities; Bicycle Sharing; Bus Design; Complete Streets; Transit Centers; Transit Lines/Networks.

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Bicycling, Health and Recreational Aspects of

Bicycling has great positive effects on the physical and psychological health and recreational outlook of individuals and communities. The health and recreational aspects of bicycling and related activities are diverse and vary across culture, place, time, and other dimensions. New forms of bicycling recreation continue to emerge over time, and there are ebbs and flows of the popularity of a particular discipline

or activity. Similarly, health benefits of bicycling become apparent through new research. The capacity of bicycling to simultaneously fulfill multiple objectives, such as recreation, health, transportation, and mobility, is a major theme in understanding and assessing the benefits of bicycling. This becomes especially evident when comparing and contrasting bicycling with other travel modes.

Definitions

Alley cat. An informal bike race, originating in bike courier culture and often organized by messengers. There are several formats, most often involving checkpoints that may be revealed before the start or may be assigned one at a time as in a scavenger hunt. Racers carry a manifest that must be marked at each check station. There are no fixed routes, only checkpoints. Participants may be required to perform tasks or antics at a check station to have their manifest marked. Alley cats may take the form of a scavenger hunt–style point-collection race.

Bike building. The assembly of a bicycle. Most factory-built bicycles are shipped partially assembled and are finally assembled and adjusted by the retailer. High-end and custom bikes are often assembled from individual components by a bicycle shop or enthusiast/owner.

Bike polo. A sport derived and adapted from horse-mounted polo, originated in Ireland in the late 1800s. The earliest bike polo was played on grass fields, like conventional polo. Contemporary bike polo, which was popularized in Seattle in the late 1990s and spread globally, is played on asphalt or concrete and is known as hardcourt bike polo.

BMX. Bicycle Moto Cross, adapted from the “MX” abbreviation for motocross racing that inspired BMX riding and racing. BMX originated in Southern California in the 1970s with dirt track racing on 20-inch-wheel one-speed bicycles; there are also BMX cruiser bikes with 24- or 26-inch wheels. BMX tracks often have a starting gate and a high-speed serpentine course with various types of jumps and berms that racers traverse in a sprint to the finish line. Racers compete in qualifying rounds known as “Motos” leading up to the “Main” race. BMX stunt riding has become more popular than racing. BMXers ride skate parks, plywood ramps, and found

street obstacles as well as constructed trails and dirt jumps. Many stunts involve technical maneuvers while airborne. BMX shares terrain, some tricks, and cultural elements with skateboarding.

Chopper. (1) any sort of garage-modified bicycle; (2) a bike with a relaxed head angle and extremely long fork, analogous to a motorcycle chopper.

Ciclovía/open streets events. These are planned and organized celebrations of nonmotorized and pedestrian travel. During these events, streets are closed to motor vehicles for the day or for several hours to allow citizens to walk, pedal, and skate in an ephemeral nonmotorized space. These events may include and be focused around a bicycle parade. Seattle’s Bicycle Sundays, beginning in 1965, and Bogota’s Ciclovía, operating since 1978, are two of the longest running Open Streets events.

Critical mass. A nonorganized event, occurring the last Friday of every month during the evening rush-hour, typically beginning at 6:00 P.M. Riders congregate and make a spontaneous, nonpermitted bicycle parade through the city, generally without a preplanned route. This 20-year-old happening, which has operated as an emergent phenomenon in over 450 cities globally, began in San Francisco and quickly spread to other cities in the United States and abroad. It is simultaneously a festival, a celebration of cycling, and a protest against poor existing conditions for bicycle riders.

Cyclocross. Also known as CX or “cross” racing, cyclocross is a form of off-road racing, primarily done on 700c wheel drop bar–equipped bicycles originally derived from road racing bikes. Cyclocross originated in western Europe as a form of winter training for bicycle racers. In this fall and winter sport, racers ride off-road over rough terrain doing multiple laps on a short, technical course.

Frame building. The construction of a bicycle frame. Metal frames are typically tungsten inert gas (TIG) welded, fillet brazed or lugged, and brazed from steel, aluminum, or titanium. Metal bicycle frames have largely been built from materials ranging in quality from mild steel to high-strength super alloys of steel, aluminum, and titanium, though magnesium has also been used.

Since the mid-1990s, aluminum frames have become much more common. Carbon fiber has become the material of choice for racing and high-performance bikes in many disciplines of cycling and has become increasingly common.

Gran fondo. “Large Ride” from the Italian. Also known in French as *Cyclo sportive*; a large mass-start social ride for riders of varying fitness and skill. The events are noncompetitive but they do have a maximum completion time.

Lowrider. A bicycle with low bottom bracket, short cranks, and a low saddle; often decorated extensively and elaborately in the fashion of a lowrider car. Lowrider bikes often have a springer fork, a banana-type seat, and very high-rise “ape hanger” handlebars and ample chrome plating. They may include mirrors and other accessories, faux fuel tanks, or other motorcycle-inspired adornments.

Tallbike. A bicycle that is significantly taller than a typical bicycle, typically made from two bicycle frames welded, brazed, or bolted one atop the other. The rider cannot straddle the top tube of the frame with his/her feet on the ground. Presently, these bikes are made and used for hobby and recreation. Historically, lamp lighters used purpose-built tall bicycles to light gas street lamps.

Touring. Bicycle touring is a pastime of traveling by bicycle and takes many forms. Self-supported overnight and multiday trips are popular, as are lightweight “credit card tours” on which riders pay for accommodations and prepared food instead of carrying camping and cooking gear. Van- and crew-supported bike tour packages are also popular, and there are a number of firms specializing in supported tours, local and international. Gravel road and off-road touring continues to gain popularity as do all forms of bicycle touring. Bike touring has proven to be a great boon to some rural economies along popular bike routes. Purpose-built touring bikes are popular and have their advantages, though it is feasible to tour on many different types of equipment.

Randonneuring. An organized, noncompetitive, self-supported, long-distance bike-riding activity. Randonneurs often ride long distances in a single

push, through the night, without significant sleep breaks. The organized rides take on different names with varying length. For example, a brevet is 200 kilometers. These rides require riders to reach checkpoints called controls. Riders are required to complete each segment within a specified time range. Fast riders are made to wait at controls and riders moving too slowly are disqualified. In terms of frame geometry, a randonneuring bike is between a road-racing bike and a touring bike and is designed to carry a light load with small racks to support dedicated bags. They often include integrated generator-powered lights and fenders. While dedicated randonneuring bikes are popular, other types of bikes can be adapted for the purpose.

Recreation. An activity done away from work time that is refreshing or fun. For example, professional bike racers are not recreating while they are training or racing, though they may be while riding with their families.

Safe Routes to School (SRTS): An international movement promoting active transportation to schools for elementary and middle school students. The programs focus on walking and biking safety and encouragement. SRTS is based on the principles of the “Five Es”: education, encouragement, evaluation, engineering, and enforcement. The program originated in Denmark in the late 1970s and the first Safe Routes program in the United States was in the Bronx in 1997. In 2000 the U.S. Congress funded two pilot programs in Marin County, California, and Arlington, Massachusetts, for the 2000–01 school year. In 2005 Congress formalized the program and provided a five-year funding package as part of the SAFETEA-LU legislation.

Velodrome Track: Track riding and racing is done on a velodrome, indoor or outdoor. A velodrome is a smooth, hard-surface race course for bicycles. Velodromes are typically ovals with banked corners and are constructed of wood, concrete, or asphalt. Racers compete on fixed-gear bicycles, which do not freewheel, without brakes. As with other forms of bike racing, there are several disciplines of track riding, including various individual and team events.

Wheel building: The assembly of a wheel from its component parts, including rim, hub, spokes, and

spoke nipples; the assembly steps include lacing, tensioning truing, stress-relieving, and final tensioning.

Health Aspects of Bicycling

While most physical activity is beneficial to the participant, bicycling offers a multitude of benefits. The health impacts of biking are not only physically beneficial but can also holistically improve psychology, emotion, and community. Bicycling is compelling in part because it is so versatile and can achieve many goals and purposes, often simultaneously, and while it can be, it does not need to be viewed as sport. Bicycle riders can be subject to acute and chronic injury, though these are largely avoidable with due care and safe practices.

The physical activity benefits of biking are many. Bicycling offers a balance of muscular and cardiovascular exercise; it is a non-jarring and low-impact workout with a low risk of overuse injuries. Bicycling has benefits for many systems of the human body, including the musculoskeletal, immune, nervous, endocrine, digestive, pulmonary, and cardiovascular systems. The benefits of bicycling for these organ systems lead to improved outcomes for strength, flexibility, body mass, blood sugar, cholesterol levels, blood pressure, agility, and muscle tone. Different disciplines of bicycling place different demands on the body. For example, mountain biking and BMX riding demand more from the upper body muscles than does road riding.

Most bicycle riding takes place outdoors, which provides significant health benefits, including access to fresh air and sunshine, opportunities for spontaneity, and social interaction. The vitamin D production in human skin that occurs with sun exposure is a notable health benefit of biking, but solar rays also carry harmful ultraviolet and infrared light that can lead to skin and eye damage; sun protection for eyes and skin is important.

Bicycling can be especially good for joint health. For example, cycling strengthens the muscles that support the knee joint, in particular, the *vastus medialis*, which helps control the *patella* (kneecap) and can help correct knee problems. In contrast, most disciplines and forms of bicycling are not particularly good for bone health because there is not enough impact and weight bearing to improve bone density. This can be a concern for those with low bone density and high mileage bike riders who do not engage in other physical activities for cross training.

Psychological and Social Health Benefits

Bicycling is reported by participants and researchers alike to have great positive effects on the mood and psychological state of participants. Bicycling is sometimes referred to as the happiest mode, and this notion is supported by recent research. Bike riding can make people happier, and in particular, bicycle commuters arrive at work with a better attitude than their car-driving and bus-riding counterparts. Bicycling is good for self-image, mood, emotional health, happiness, and self-actualization.

Commute travel is a considerable source of anxiety for many, so the benefits of bicycle commuting can be especially dramatic as seen in contrast to other travel modes. All types of bicycling can also offer mental and physical health rewards. While there are many physiological health benefits of bicycling, the psychological benefits should not be overlooked. Bicycling is good for the mood and can help focus the embodied mind. Bicycle riders receive a measure of psychic income each time they ride their bike; this may come in the form of a feeling of well-being, improvement in mood, exhilaration, autonomy, or self-reliance.

Bicycling is good for individual health and community health. The ecological, land use, and transportation benefits of bicycling help improve community health in objective and measurable ways. Bicycling also offers opportunities for social interaction within a community, beyond what is possible between drivers of motor vehicles. Increases in bicycle ridership have been observed to improve road safety for all road users. One of the clear benefits to the broader community of bicycling is the reduction in fuel and power consumption and air pollution created by bicyclists forgoing motorized travel. Under the rubric of community health, access to active transportation can easily be seen as a public health and social justice issue. Biking makes accessibility and mobility better, and communities that lack opportunities for bicycle and pedestrian travel are not serving the needs of their residents.

In addition to offering many health benefits, bicycling also presents some risk of acute and chronic injury. The majority of acute bicycling injuries are the result of falls caused by a rider losing control of his/her bike and are, therefore, avoidable. Chronic injury from repetitive stress can be avoided through proper fit and good ergonomics. To avoid these chronic injuries, the size of the bicycle should

match the size of the rider, and the relationship of the saddle, handlebars, and pedals of a bicycle should be carefully adjusted for the individual.

Recreational Aspects

Recreational bicycling is often associated with amateur racing, group rides, touring, and large organized rides. These are all popular and important forms of recreational bicycling, but there is much more to bicycle recreation. As bicycling becomes increasingly popular as an everyday activity, there are corresponding increases in organized, noncompetitive events that are focused on the conviviality of the experience and less oriented toward competition and rankings, such as Gran Fondos and Ciclovía events. Additionally, the material cultures of bicycling are becoming increasingly visible in mainstream culture, on and off the bike.

There are many diverse and emerging forms of bicycle recreation. Social change and trends lead to ebbs and flows in the popularity of a discipline or subdiscipline of bicycling. There are also many bicycle and bicycling-related recreational activities that do not necessarily include riding bicycles, such as bicycle repair and maintenance, assembly and production, and bike art, which can include creation and display of photography, painting, video, film, sculpture and furniture made from bike parts.

Utilitarian and commute bicycling are often thought of as separate from recreational bicycling, but a given trip can be understood to fulfill multiple purposes—recreational and utilitarian. Not every bicycle trip has a recreational element but many do, even if they also have a utilitarian purpose. Utilitarian bicycle trips simultaneously deliver the health benefits of exercise and allow utility bicycle riders to skip gym workouts and other workout routines.

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See Also: Bicycle Commuting; Bicycle Safety; Recreational Travel.

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Bikeways/Bike Lanes, Road Design Issues of

Bikeways, or bike lanes, are dedicated road infrastructure for cycling. Their need derives directly from the difference in travel speed of bicycles and motorized vehicles such as cars, buses, and motorcycles. The choice of the type of cycling infrastructure to be implemented in a road segment is first and foremost connected to the desired and/or planned travel speed for a certain road segment. The basic goals of the design of cycling infrastructure are to reduce delays or diversion and to improve cycling safety.

Bikeways are one of several ways of improving cycling conditions in an urban area, and indeed other priority measures should be taken as well. By order of priority, the following measures should be applied: reducing traffic volume, reducing traffic speed, junction treatment and traffic management, reallocation of carriageway space, building/improving bikeways, and converting footpaths to shared use. As a general principle, removing pedestrian space should not be an option when creating cycling space. These measures should also be combined when designing a cycle network, once the network can be made of different typologies along the route.

Network Requirement Principles

Cycling infrastructure must be designed in accordance with five main requirements, which are coherence, directness, safety, comfort, and attractiveness:

Coherence. Cycling infrastructure must be complete, creating a coherent whole. Cycling infrastructure should guarantee connections between main origins and destinations, through a coherent, whole system, giving opportunity to all people to go somewhere by bicycle. Safe bicycle parking at origins and destinations directly contributes to coherence. Other key elements are signaling and marking, consistent quality of the infrastructure, and ensuring that different routes are available.

Directness. Cycling infrastructure must allow cyclists to reduce travel time and travel distance, so cyclists can choose the most direct route, minimizing detours as much as possible. Factors that can contribute to reducing travel time include traffic lights, crossing of busy main roads, and detours. Design elements with a clear influence are cycle shortcuts between roads, allowing two-way cycle traffic on one-way roads (contraflow lanes), and implementing two-way cycle lanes on both sides of main roads to avoid crossings.

Safety. Cycling infrastructure should ensure the safety of cyclists and of other road users. Cyclists are vulnerable road users as they do not have external protection and show considerable differences in terms of mass and speed to motorized modes. Visibility is a main issue of cycling safety, and in dark or rainy weather cyclists' vulnerability increases due to the decrease in overall visibility.

Design is paramount to ensuring cycling safety, avoiding encounters with fast-moving motorized traffic. Important elements are the implementation of traffic calming measures, minimizing the need to travel along dangerous roads, providing clear signage and indications of routes, reducing the number of traffic solutions, reducing speed at junctions, and separating different vehicles where speed reduction is not possible.

Comfort. Cycling infrastructure should allow a comfortable cycle ride. The average urban bicycle has no suspension, and so a smooth surface should be offered in order to provide comfort. Poor surfacing,

bottlenecks, and shortcomings in infrastructure are a source of nuisance and delays. Minimizing chance of stopping and annoyance caused by other traffic and weather should be ensured.

Attractiveness. Cycling infrastructure should fit well with surroundings. In order to increase attractiveness, it is extremely important to listen to cyclists' complaints and provide adequate answers to them. Attractiveness is also related to social safety, as cyclists feel safer in busy places.

All these principles are important when designing cycling infrastructure; however, different priorities may be given in accordance with the different users' needs. A clear indication of poorly conceived and designed cycling infrastructure is its disregard by cyclists, riding on the road instead, mixed with other traffic.

Types of Cyclists

Different cyclists have different abilities to cycle, especially with regard to travel speed and willingness to mix with motor traffic. It is common to consider five different categories of cyclists:

- *Fast commuter:* A highly confident cyclist, willing to mix with motor traffic in order to reduce travel distance
- *Utility cyclist:* A confident cyclist, but may require some segregation on busy junctions and on segments with high-speed and/or high-volume motor traffic
- *Inexperienced and leisure cyclist:* Values safety at the expense of directness, searches for routes with less traffic
- *Children:* Safety is paramount; segregated routes are normally required for access to schools, even if on-road solution exists; additional width should be considered in order to accommodate parents escorting children side-by-side
- *Users of special equipment:* Cyclists with trailers, tandems, and tricycles require additional width for riding and overtaking

In order to attend to all users' needs, it may be necessary to implement dual networks, one with more segregation from motor traffic at the expense of directness, dedicated to inexperienced and

leisure cyclists, children, and other users with special equipment.

Types of Bicycle Facilities

Cycling facilities can take the form of cycle tracks or paths (bikeways), and cycle lanes. The main difference between them is the type of segregation: cycle tracks or cycle paths are physically segregated and cycle lanes are visually segregated. Nevertheless, cycling is possible and common on roads without dedicated cycling infrastructure, if traffic speed is slow and traffic flow is small.

Cycle tracks take more space than cycle lanes but provide better protection to cyclists, facilitate overtaking by cars, and make cycling less affected by congestion. However, if they cannot be properly applied in intersections, all these advantages are lost and accidents can increase. Other disadvantages include loss of freedom to cyclists and less awareness from drivers who tend to speed more. Segregation can be accommodated by a strip of grass, a curb, setting the lane at a different level, or putting in other elements like a line of trees, posts, or other barriers.

Cycle lanes are easier and less expensive to implement, but they require slower traffic speed from motorized traffic in order to provide adequate safety to cyclists. They are also hard to implement on roads with large volumes of traffic or heavy vehicles. Cycle lanes make cycling visible to drivers and express equality of all road users, contributing to raising awareness of cycling. They should be the most common solution in cities, together with speed reduction techniques.

Two basic criteria should be used in order to choose the right type of cycling facility: the 85th percentile speed and traffic flow. Cycle tracks or cycle paths are recommended for segments with speeds higher than 30 miles per hour (mph) (50 kilometers per hour [km/h]) or more than 10,000 vehicles per day (vpd). If the 85th percentile speed is below 20 mph (30 km/h) and traffic flow is lower than 6,000 vpd, no dedicated cycling infrastructure is needed, as cycling is possible mixed with traffic. Cycle lanes are recommended for intermediate situations.

Besides these general criteria, in streets with slow traffic, increasing the width of the near-side lane can make a cycle lane unnecessary, as it increases clearance when overtaking. Likewise,

on high traffic streets with many side roads, bus stops, and other curbside accesses, cycle lanes may be of little use, making it preferable to reduce traffic speed and increase lane width rather than provide cycle lanes.

On streets with significant gradient, a cycle lane is extremely beneficial in the uphill direction, but it can make cycling conditions worse in the downhill direction, as speed differential going down can be irrelevant. In these cases, it is often preferable to have a wide single bike lane going up rather than to have two narrow lanes in both directions.

On one-way streets, contraflow cycle lanes should be considered if they could be safely accommodated on the street, as cyclists tend to ride these streets both ways in order to increase directness.

General Design Parameters

In order to ride comfortably and safely, a cyclist needs space that depends on the cyclist's dynamic envelope, the clearance to fixed objects, and the distance from other traffic. Increased speed differential between cyclists and other motorized traffic requires additional separation.

Dimensions of Cycles

A typical bicycle is 6 feet (180 centimeters [cm]) long and 2 feet (65 cm) wide, but other, nonstandard cycles should also be considered when designing cycling infrastructure. Minimum turning circles for a typical bicycle is 2.8 feet (85 cm) inner radius and 5.4 feet (165 cm) outer radius, but it depends on the ability of the cyclist to turn at low speed. Tandems, tricycles, and trailers increase both length and width of the cycle, and so additional width and turning circles should be considered—for a tandem, the minimum values are 7.4 feet (225 cm) inner radius and 10.3 feet (315 cm) outer radius.

Dynamic Envelope

Cyclists do not ride in a straight line. In order to sway the bicycle, cyclists need a space larger than their shoulders' width. To keep a straight line and to balance the bike without a conscious effort, cyclists need to ride at a speed of 7 mph (11 km/h) or greater. At this speed, cyclists need 8 inches (0.2 meters [m]) additional shoulder width. Below this value deviation increases, reaching typically 2.6 feet (0.8 m) at 3 mph (5 km/h). A dynamic envelope of 3.3 feet (1.0 m) width should be considered.

Distances to Fixed Objects and Other Cyclists

When passing fixed objects, cyclists need additional space that varies in accordance with the height of the object. Curbs less than 2 inches (50 mm) high require 10 inches (0.25 m); curbs over 10 inches require 1.6 feet (0.5 m); signposts, columns, etc., require 2.5 feet (0.75 m); and continuous features such as walls require 3.3 feet (1.0 m).

In order to allow cyclists to pass each other, a separation of at least 1.5 feet should be provided between the dynamic envelopes of each cyclist, requiring a minimum width of 8.2 feet (2.5 m) for a two-way cycle track.

Safe Passing Distances

The safe passing distance between cars and cyclists should increase with the driving speed. At 20 mph (30 km/h) cars normally pass leaving a 2.8 foot (0.85 m) clearance space, which may be stressful and uncomfortable to some cyclists. Minimum suggested passing distances are 3.3 feet (1.0 m) for cars passing at 20 mph and 5 feet (1.5 m) for cars passing at 30 mph (45 km/h).

Cycle Lanes Design

Cycle lanes are intended to improve cycling conditions, but poorly designed infrastructure can worsen cycling conditions. Cycle lanes are needed whenever the speed differential between cyclists and motorized traffic is high. Therefore, slowing traffic speed can be as efficient as cycle lanes in increasing cycling conditions. As mentioned above, where 85th percentile speed is less than 20 mph (30 km/h), cycle lanes are generally not necessary.

Cycle lanes can be mandatory or advisory. Mandatory cycle lanes are marked by a continuous white line and are to be used exclusively by bicycles. When these mandatory cycle lanes cross side roads, advisory cycle lanes should replace them in order to allow other vehicles to cross. Although not necessary, these mandatory cycle lanes should have double no-parking lines alongside the curb in order to discourage motor vehicles from parking on the lanes. Advisory cycle lanes are normally marked by discontinuous white lines and are adequate to guide cycle traffic in large and/or complex junctions. Advisory cycle lanes are also adequate to raise driver awareness of the presence of cyclists and are recommended on streets with ample carriageway width.

As a general rule, the minimum recommended lane width is 6.6 feet (2 m), as it allows cyclists to overtake other slower cyclists, to remain in the cycle lane when checking for traffic, and to avoid curb-side drainage grates and debris. On streets with significant traffic or traveling at more than 40 mph (60 km/h) this is the recommended minimum width. On streets with a 30 mph (50 km/h) speed limit a minimum width of 5 feet (1.5 m) is normally accepted. It is acceptable to reduce lane width to 4 feet (1.2 m) for cycle feeder lanes to advanced stop lines (bike boxes, see below). Cycle lanes narrower than 4 feet are not acceptable in any case, as they cannot accommodate tricycles or bicycles with trailers.

If the cycle lane is located in a street with allowed parallel parking, there is need to implement a buffer zone of between 1.6 foot (0.5 m) to 3.3 foot (1 m) widths alongside parking, in order to accommodate the additional space required to load and unload the car.

Two-way cycle lanes are not generally recommended and should be avoided because they are normally confusing to car drivers and can be significantly dangerous when crossing a road. When a two-way cycle lane crosses a road, some of the cycle traffic will present itself as contraflow to the car driver, increasing the probability of an accident. Nevertheless, in some specific segments they can be applied, but a physical segregation should be implemented (a curb or other element). Examples are dedicated cycling underpasses or bridges of major junctions or leisure cycle lanes along parks and other green areas. Another example is using the central median of the street to locate a two-way cycle lane. The minimum width of a two-way cycle lane is 8.2 feet (2.5 m).

Intersections

Intersections are specific cases in a cycling network that require particular attention and detail—if poorly designed, they can contribute to accidents, and 70 percent of accidents involving cyclists occur in intersections. Visibility and safety are paramount.

For signalized intersections, a common, safe and affordable solution is the introduction of advanced stop lines (ASL) with a cycle feeder lane. This solution enables cyclists to overcome motor vehicles on the approach to the junction and to position themselves in the right place for their intended maneuver while the signal is red. An ASL is made up of a stop



A bicyclist stopped at an intersection with a two-way bike lane in Lille, France. Two-way bike lanes are recommended only for limited situations and normally require 8.2 feet (2.5 m) of space.

line for motor vehicles, an additional stop line for cyclists near the signal, and a lead-in (feeder) cycle lane. The area between the two stop lines forms a reservoir for waiting cyclists and should be between 13 to 16.4 feet (4 and 5 meters) deep. Lead-in lanes can be mandatory or advisory and should have 4 foot (1.2 m) minimum width. Non-nearside lead-in lanes are extremely useful when the nearside lane is dedicated to vehicles turning right. In this case, they should be marked as advisory lanes and, as they will be located between two lanes of moving traffic, a minimum width of 6.6 feet (2 m) is recommended. Applying a colored surface on ASL and feeder lanes is useful to increase visibility.

An alternative to ASL is commanding the left turn in two stages. In this case, left turns are not

allowed and cyclists have to move forward and wait at the stop line of the perpendicular road in order to turn left. This solution increases safety, but it also can increase overall travel time.

Raised tables are extremely useful in intersections as they reduce overall traffic speed. Raised tables that occupy the entire intersection can be used at priority junctions, making separate cycle facilities unnecessary.

Roundabouts

Roundabouts are special cases of intersections in which the risk of a cyclist accident is higher. Due to the process of motorized vehicles entering and leaving the roundabout, riding near the curb puts cyclists in the most dangerous position. A main improvement in the negotiation and ride of a roundabout by a cyclist is overall traffic speed reduction.

Cycle lanes on roundabouts are indeed not proven to contribute to an increase in safety. If present, they should occupy a position in the center of the carriageway and be accompanied by speed reduction measures. Redesigning entry and exits lanes to a more radial than tangential position is also recommended. In large roundabouts, alternative routes or the introduction of peripheral segmented cycle tracks should be considered, with signalized crossings on the roundabout arms.

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See Also: Bicycle Facilities; Bicycles; Bicycle–Transit Linkages; Road Diets; Roundabouts and Traffic Circles; Traffic Calming.

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Biodiesel

Scarcity of known petroleum reserves and growing international concern with regard to climate change have resulted in the search for renewable and economically viable sources of alternative energy for transport. Biodiesel in particular is a type of biofuel that has been in the forefront of such alternative technologies, even though the extent to which it meets both the aforementioned criteria in practice is being increasingly questioned.

Biodiesel has received significant attention due to its similarity to conventional diesel in terms of energy content and chemical structure. It is produced from the reaction of vegetable oils or animal fats with an alcohol. Producing biodiesel from such sources is not a new process. In the 1900s, Rudolf Diesel had actually designed the original diesel engine to run on peanut oil. Low fossil-fuel prices prevented the further development of biofuels in general for the most part of the 20th century, but interest in commercial production was stimulated as a result of the two oil crises in the 1970s.

Biodiesel can either be used directly or as a blend with petroleum-based diesel. The level of blending is designated "Bxx," with "xx" indicating the amount of biodiesel in the overall blend. For example, various concentrations are currently present in the market, such as pure (B100), blends (B20–B30), additive (B5), and lubricity additive (B2).

Feedstocks

There are various raw materials that can be used as feedstock for biodiesel production. To begin with, edible vegetable oils are the most common source. For instance, rapeseed is the most important feedstock in the European Union, palm oil in Malaysia, and soy in Brazil and the United States. The fact, however, that neat edible oil competes with food supply has resulted in biodiesel from such sources becoming increasingly embroiled in controversy.

Consequently, using nonedible oils so as to avoid conflict with food consumption has emerged as an attractive policy option. *Jatropha*, castor, and rubber seed serve here as representative examples. *Jatropha* in particular was once thought of as the "miracle crop" for the production of biodiesel, given that *Jatropha* is a drought-resistant, nonedible perennial that can be planted on marginal land and requires limited water or agrochemical supply. So

far this potential has not been realized, as there are still large knowledge gaps that need to be addressed before fully commercializing *Jatropha* oil.

Waste oils, grease, and animal fats can also be used as feedstock for biodiesel production. One of the benefits of relying on such sources is that doing so eliminates the environmentally damaging practice of having to dispose of them. Yet developing the requisite collection infrastructure and dealing with logistics and quality control issues can be major challenges, especially with regard to waste oils and grease. Relying on animal fats poses less of a hurdle, given that the slaughter industry is generally well managed in such respects. There is, however, a bio-safety concern that needs to be taken into account, as contaminated animals could potentially be the source of animal fats.

Finally, algae has been receiving growing attention in terms of biodiesel production as it does not impact food production and has a far superior yield per hectare over conventional oil crops. Producing algae to harvest oil for biodiesel has not been undertaken on a commercial scale due to high production costs and the several scientific uncertainties that still need to be addressed.

Advantages and Disadvantages of Biodiesel

Biodiesel has a number of technical advantages compared to petroleum diesel fuel. To start with, it runs well in unmodified conventional engines and, as a result of its better lubricating qualities, it actually prolongs their lives, thereby reducing the need for maintenance. In addition, storage, transportation, and distribution to end users are identical to those of fossil diesel. Finally, biodiesel is safer to handle, as it is less toxic, more biodegradable, and has a high flash point compared to petroleum diesel fuel.

Regarding its emissions profile, the use of biodiesel in conventional diesel engines provides substantial reductions in emissions of inter alia carbon monoxide, sulfur oxide, unburned hydrocarbons (HC), and polycyclic aromatic hydrocarbons (PAHs). In addition, emissions of carbon dioxide are also significantly reduced, which is quite important given that climate change is considered the most pressing global environmental concern. Regarding nitrogen oxides, the literature is currently divided as to whether biodiesel results in an increase or decrease of their emissions.

Turning to technical disadvantages, the main problem associated with the use of biodiesel concerns poor cold-starting performance, as the fuel begins to gel at low temperatures. An equally important drawback concerns biodiesel's higher price compared to fossil diesel. This is due to high feedstock price, as the cost of raw materials accounts for about three to four quarters of the total production cost of biodiesel. Other major technical disadvantages include lower energy content, higher viscosity, injector coking, higher cloud and pour point, degradation of fuel under storage for prolonged periods, and others. Apart from technical disadvantages, there are also complications with regard to the sustainability of biofuels, which are outlined in the following section.

Biodiesel and Sustainable Development

The production and consumption of biofuels in general and biodiesel in particular have been met with a number of criticisms, namely, that they do not contribute to all three dimensions of sustainable development (society, environment, and economy). Some of the main criticisms are outlined below.

Starting with social sustainability, criticisms here concern the fact that biodiesel production does not take into account its impact on food prices and production. More than 95 percent of biodiesel production relies on edible oils, causing concern that large-scale biodiesel production could potentially destabilize the global food supply-and-demand market. There is currently a high degree of skepticism in the literature as to whether arable land should be used to grow biodiesel feedstock instead of food.

Turning to environmental sustainability, the worldwide expansion of oil-crop plantations to meet increased biodiesel consumption has been held responsible for widespread deforestation and ecosystem degradation in countries like Brazil, Thailand, Indonesia, and Malaysia. As a result, releasing carbon that has been locked away for thousands of years could therefore actually accelerate the effects of climate change.

Closing with economic sustainability, tariffs and subsidies are the two main mechanisms governments generally use in order to support their national biofuels industries. Such support measures, however, distort international trade by hindering imports of biofuels that are cheaper and far

more energy efficient. For example, biodiesel production in the European Union is not profitable without heavy subsidization. In addition, European Union biodiesel production is based on rapeseed, a feedstock considerably low in energy per hectare and in greenhouse gas savings. Support mechanisms therefore entail promoting biofuels that are often more expensive and far less energy efficient compared to their counterparts in tropical countries, for example, Brazilian sugarcane-based bioethanol.

Biodiesel Policies Around the World

Starting with the European Union, in excess of three-quarters of the demand for biofuels is met by biodiesel. The European Union is by far the world's leading producer. Ethanol accounts for some 20 percent. So far, the European Union has adopted two directives on biofuels. The first, the Biofuels Directive of 2003, contained a set of indicative targets for biofuels (2 percent by 2005, rising to 5.75 percent by 2010). Only seven member states (Germany, Sweden, France, Poland, Austria, Portugal, and Slovakia) have met the 5.75 percent figure, with the European Union overall having achieved 4.7 percent in 2010.

The second directive, the Renewable Energy Directive of 2009, contains a mandatory 10 percent biofuels target to be reached by 2020. This 2009 directive also contains (following widespread criticism from nongovernmental organizations) a number of sustainability criteria on the production and use of biofuels in the European Common Market. To begin with, the directive stipulates that biofuels must emit a minimum of 35 percent less greenhouse gas than the fossil fuels they replace. This percentage is set to rise to 50 percent in 2017. In addition, the sustainability criteria also stipulate that biofuel feedstock is not to be derived from primary forests, lands with high biodiversity value, protected territories, and carbon-rich areas.

In Brazil, ethanol production for transportation purposes has a long history, going back to the 1970s. However, the Brazilian government launched in 2004 the National Biodiesel Production and Usage Program (PNPB) in order to encourage the introduction of this biofuel into its energy mix. In the initial stages, refiners and distributors were adding 2 percent biodiesel to diesel. The PNPB proved to be quite successful, with biodiesel production

more than tripling between 2005 and 2010, making Brazil the second-largest biodiesel producer worldwide. As a result, the Brazilian government decided in 2010 to promulgate B5 as the mandatory blend. According to the PNPB, palm oil in the north, castor oil in the northeast, and soy and other crops in the remaining regions should comprise the preferred feedstock.

Special note should be made of the fact that one of the aims of the PNPB is to foster social inclusion through the generation of income for small producers. A Social Fuel Seal certificate is therefore awarded by the government to biodiesel producers who inter alia purchase a minimum percentage of feedstocks from family farmers and provide them with technical assistance.

The biodiesel industry in the United States is much younger and smaller compared to that for ethanol. Even so, biodiesel production and consumption have increased steadily over the years. As a result of its relatively low price, soybean oil is the most commonly used feedstock, accounting for over 50 percent of national production.

The U.S. Environmental Protection Agency (EPA) in 2010 established the so-called Renewable Fuels Standard (RFS2). This applies only to biofuels and mandates the consumption of a certain amount of biofuels per year until 2022. For example, the EPA had required that 800 million gallons of biodiesel were to be consumed across the United States during 2011. This figure went up to 1 billion gallons with regard to 2012, while the figure released for 2013 by the EPA was 1.28 billion gallons. With regard to sustainability, the RFS2 requires that biodiesel must demonstrate greenhouse gas emissions savings over its life cycle of 50 percent per gallon relative to petroleum-based diesel fuel.

Conclusion

Biodiesel as a fuel is much less polluting than petroleum diesel, achieving much lower emissions of almost every pollutant: carbon dioxide, particulates, carbon monoxide, and others. Biodiesel production, however, has been linked to unsustainable practices across the world, raising doubts with regard to the extent it can contribute meaningfully toward sustainable development.

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See Also: Air Pollution/Air Quality; Alternative Automotive Fuels; Alternative Fuels; Biofuels; Diesel Engines; Diesel Fuel Vehicles; Ethanol; Green Fuels.

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Biofuels

Biofuels for transport are liquid or gas renewable energy sources that are produced from biomass and can be used as a substitute or blend for petroleum fuels. Once thought of as a viable green alternative, the debate today over biofuels provokes strong responses from people on both sides, as experts, nongovernmental organizations, and corporate actors are sharply divided concerning their sustainability.

Contrary to general belief, biofuels for transport have been in use since the late 19th century, even though large-scale industrial production is a more recent development. The first national-level program was launched in 1975 in Brazil, with ethanol being produced from sugarcane. The United States soon followed suit, using corn as the prime feedstock. Today, these two examples have been followed by the European Union, India, China, Thailand, and several others around the world. While several different varieties of biofuels are in the market, the only ones that can be currently supplied in adequate amounts are bioethanol and biodiesel. The former is based on crops that are high in either sugar (sugarcane or sugar beet) or starch (maize and corn). The latter is based on plants that contain high amounts of vegetable oil, such as soybean or oil palm.

Types of Biofuels

Promotion of biofuels has been supported worldwide for a wide range of reasons, namely, climate change mitigation, energy security concerns, and rural development stimulation. In terms of main producers, Brazil and the United States account



A technician at the U.S. Department of Energy's Argonne National Laboratory in April 2010 compares bacteria samples growing on media containing two different antibiotics. The bacteria was being studied for possible use in biofuel production.

for approximately two-thirds of global ethanol supply, while the European Union (mainly Germany, France, and Italy), Argentina, and the United States are topping the list with regard to biodiesel.

Biofuels from food sources are collectively known as first-generation biofuels. In order to avoid competition with food production, developing second-generation biofuels has been increasingly viewed as a more attractive option, as these are produced from inedible sources, such as woody crops, energy grasses, or even agricultural and forestry residues. However, unlike the easily processed first-generation biofuels, the complex substances found in the woody or inedible tissues of plants are much more challenging to chemically process and convert to energy with currently available methods. Consequently, several technological breakthroughs are still required for second-generation biofuels to become commercially viable. The same is true of third-generation biofuels, which are based on marine algae and seaweeds. A substantive amount of further research and development is required

before establishing an economical industrial-scale production of algal biofuels.

Sustainability of Biofuels

In what constitutes a classic example of policy running ahead of science, several governments rushed to set up biofuels programs without having carried out in advance a thorough assessment of all the pros and cons associated with biofuels commercialization. First-generation biofuels in particular have become embroiled in some of the most highly contentious debates on the current international sustainability agenda, given their links to energy security, transport, trade, food security, land use, and climate change concerns. A number of the most controversial sustainability complications of biofuels are outlined below.

To begin with, there has been growing concern with regard to the energy efficiency of biofuels. It should be noted at this point that biofuel sustainability depends on the type of feedstock crop used, the cultivation methods, and processing techniques. On one hand, for example, a growing body of research has recognized sugarcane-based ethanol as the most energy-efficient and price-competitive biofuel worldwide. On the other hand, palm oil biofuels have been held responsible for causing damaging deforestation and reducing biodiversity, whereas study results have consistently highlighted the poor energy efficiency properties of corn-based ethanol.

Another major environmental concern with biofuels production is that their increased production and consumption could cause considerable land use change (LUC), both direct (dLUC) as well as indirect (iLUC). In particular, measuring iLUC (e.g., biofuel plantations replace pasturelands, which replace forests) is scientifically quite challenging, with consensus as to how to monitor and control it being currently lacking. Scholars have argued, for instance, that even carbon savings from Brazil's highly energy-efficient sugarcane-based biofuels could be offset if iLUC changes were factored in, especially those pushing the rangeland frontier into the Amazonian tropical forest region.

Finally, biofuels use has been criticized for not taking into account the impact of biofuels on food prices and availability. The argument here goes that dedicating a sizable part of the harvest production to biofuels could potentially drive food prices up and lead to food shortages and urban

riots. As a result of alarming increases in food prices between 2007 and mid-2008, several riots erupted in several developing countries around the world, including Mexico, Haiti, Yemen, and Zimbabwe. The literature is currently divided as to whether biofuels are to be held responsible, with some viewing food price increases as a direct outcome of enhanced biofuels consumption, while others mainly attributing them to factors like the rise in the cost of oil and fertilizers.

In any case, biofuels are here to stay, with more and more sectors eager to invest in accelerating their development and commercialization so as to reduce their greenhouse gas emissions. The aviation industry is one such sector, with Virgin Atlantic making pioneering test flights back in 2008 using a mixture of palm oil and coconut oil. As a result, therefore, of the policy environment highlighted above, it is imperative that all the necessary steps be taken in order to ensure that biofuels are produced and consumed in an as sustainable manner as possible.

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See Also: Alternative Automotive Fuels; Alternative Fuels; Biodiesel; Ethanol; Green Fuels.

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Bridge Design

Several factors must be considered before construction begins on any bridge. It is essential that engineers take into account not only the required length and width parameters to span the given gap but also the usage needs and anticipated volumes of the bridge, the costs and appropriateness of structural building materials, and the types and frequency of

relevant environmental conditions, such as earthquakes, tornadoes, or even annual periods of heavy rains. Taken together, all of these elements help define which of the main structural styles should be used to construct a bridge. The four principal bridge types are arch, beam, suspension, and truss. They can be used alone or in combination to create various bridge designs.

The main difference between the various bridge technologies centers on the length of a single span, which is the distance between two bridge abutments or supports that connect the bridge to the ground surface below. A single span of today's beam bridges, for example, can extend up to around 200 feet, while modern suspension bridges can extend 10 times that length or more, usually topping out at about 7,000 feet. Whichever underlying design is chosen, every bridge structure must take into account the forces of tension and compression, shear, torsion, resonance, and weather.

Types of Bridge Structure

The arch bridge is one of the oldest types of bridge design. It is founded on the principle of the Roman Arch, in which the two sides of a curved arch compress on each other at the peak, forcing tension to be pushed outward at the base. There it is controlled by supports at either end that brace the structure and make it stable enough to support a doorway, ceiling, or bridge. The ancient Romans built many arch bridges from stone and brick. Many of these 2,000-year-old structures still exist today, including the Pont du Gard aqueduct in France, which spans 300 yards at a peak height of 164 feet. The use of modern materials like steel and pressurized concrete enables contemporary arch bridges to be built with greater spans. While most arch bridges today extend to about 800 feet or less, one arch bridge in West Virginia, the New River Gorge Bridge, spans some 1,700 feet.

The beam bridge is another type of basic bridge construction that uses end supports to bear the load across its span. Beam bridges, however, use vertical or slightly angled piers to support horizontal beams that make up the deck of the bridge. The piers support the entire weight of the bridge and its traffic. The simple structure of beam bridges makes them a popular option to span short distances of approximately 250 feet or less. However, Louisiana's Lake Pontchartrain Causeway uses the beam

construction methodology to form a massive over-water bridge extending over 24 miles. To make the beam approach viable for such a great distance, engineers had to link thousands of individual beam-based spans to create the full bridge extension.

Longer bridges generally use suspension design or modern cable-stayed technologies to accommodate vast spans. Suspension bridges use two tall towers to suspend cables that support the bridge deck. The Golden Gate Bridge in San Francisco is a classic example. The towers of a suspension bridge support the bulk of the weight as compression forces push down on the deck, and then move back up the cables to the towers, dissipating the compression into the ground. The cables accommodate the tension forces on a suspension bridge by transferring the tension to the bridge anchorages that ground the bridge to the earth.

Cable-stayed bridges are a successor to traditional suspension bridges and are similar in appearance. However, they differ greatly in key design components. Specifically, cable-stayed bridges do not require anchorages or towers. Rather, their cables run from the roadway up to a single tower that shoulders all the weight and absorbs compression forces. The cables can be attached to the road in various ways, such as in a radial format, in which cables extend from multiple points on the road to a single point on the tower, or in a parallel pattern, in which the cables attach to the road and the tower at numerous points on both surfaces.

The truss bridge is a variation on the beam bridge design that features a load-bearing superstructure above, at, or below the bridge deck. It is composed of support beams connected in a triangular pattern. The use of a triangular pattern helps disperse the load burden across a wider area. Sometimes a truss formation is used to support cantilevered bridges by bracing above and/or below the bridge deck.

Structural Stressors

Tension occurs when two opposing sides of a bridge pull at each other, causing stress on the structural elements. Compression is when the structural elements press down on each other resulting in pressure stress on the structure. Each type of stress is capable of damaging the integrity of all or part of a bridge, especially as load weights and environmental factors come into play. Bridge engineers typically address these factors by choosing a design that

either dissipates the stress by spreading it out evenly over a broad area of the structure or by transferring it to stronger areas like the bridge supports.

Shear is a less likely threat to bridge safety but it does represent a viable concern for engineers. Shear stress on a bridge happens when two parts of the structure are forced in opposite directions. In a worst-case scenario, the forces of shear can rip bridge materials or the bridge itself in half.

Torsion represents another concern for bridge engineers constructing suspension bridges. Torsion occurs when high winds cause the suspended roadway to spin and bend in a motion similar to the waves of the ocean. Most of today's suspension bridges address the issue of torsion by adding a supportive aerodynamic truss system under the deck and using diagonal suspension cables to help reduce swaying and potential rippling of the roadway.

The issue of resonance involves vibrations and its effect on bridge integrity. It can begin as a comparatively minor event, such as wind battering a bridge. When the vibrations occur in relative harmony with the bridge's natural vibrations, it is not cause for alarm. If the vibration dramatically increases, however, it can send destructive vibrations resonating through the bridge structure in the form of harmful torsion waves. To reduce the effects of resonance, bridge designers typically incorporate dampeners designed to interrupt the resonant vibrations before they evolve into something more dangerous.

Weather is perhaps the greatest and most unpredictable threat to bridge construction. Natural forces such as wind, rain, snow, and ice pose ongoing concerns about bridge integrity and safety. Even some of the measures used to improve safe passage over bridges during inclement weather, such as spreading salt and sand on the roadways, can cause great damage to the structure of the bridge itself. Less frequent but more violent weather scenarios, such as hurricanes, earthquakes, and tornadoes, can destroy a bridge structure in seconds. While engineers cannot account for every scenario, they must consider potential hazards as part of their planning process.

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See Also: Benefit–Cost Analysis of Transportation; Bridge Maintenance, Repair, and Replacement; Bridges,

Condition of; Highway Design and Engineering; Institute of Traffic Engineers; Risk Analysis/Assessment; Transportation Research Board (TRB).

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Bridge Maintenance, Repair, and Replacement

Bridges are the most visible components of a transportation system. Maintaining, repairing, and replacing bridges involve critical investment decisions for agencies because of the high cost of these investments, the need to sustain an appropriate level of investment throughout the considerable life of a bridge, and the important structural and functional implications of the selected investments. Agencies, therefore, make the investment decisions to minimize life cycle cost and to provide safe and efficient mobility to transportation system users.

Most agencies use a computerized tool, a bridge management system (BMS), to manage and process relevant data and to provide analytical support for bridge program decisions. The BMS encompasses a system designed to optimize the use of available resources for the condition assessment, inspection, preventative maintenance, rehabilitation, and replacement of bridges.

Condition Assessment

Bridge structures are at risk from aging, leading to structural deterioration from severe environmental attack and service demands from increasing traffic and heavier loads, and from deferred maintenance. According to the U.S. Department of Transportation, 26.7 percent of the total bridges in the nation are either structurally deficient or functionally obsolete. The term *structurally deficient*

is used by the Federal Highway Administration (FHWA) to designate bridges eligible for federal funding. A structurally deficient bridge is one with routine maintenance concerns that do not pose a safety risk or one that is frequently flooded. To remain open to traffic, structurally deficient bridges are often posted with reduced weight limits that restrict the gross weight of vehicles using the bridges.

A structurally deficient bridge should not be confused with an unsafe bridge. A structurally deficient bridge, when open to traffic, typically requires significant maintenance and repair to remain in service and eventual rehabilitation or replacement to address deficiencies. To remain in service, structurally deficient bridges are often posted with weight limits to restrict the gross weight of vehicles to less than the maximum weight.

The term *functionally obsolete* is another FHWA term for classifying bridge eligibility for federal funding. A bridge is classified by the FHWA as functionally obsolete if it fails to meet its design criteria either by its deck geometry, its load-carrying capacity, its vertical or horizontal clearances, or the approach roadway alignment to the bridge.

Condition assessments of an existing bridge structure may be conducted to develop load rating, confirm an existing load rating, increase a load rating for future traffic, or determine whether the bridge should be posted in the interest of public safety. Changes in traffic patterns, concern about faulty building materials or construction methods, discovery of a design/construction error after the structure is in service, concern about deterioration discovered during routine inspection, and damage following extreme load events may prompt such evaluations. Posting or other restrictive actions may have a severe economic impact, which may depend on the trucking industry for distribution of resources and manufactured goods. The economics of upgrading or posting a bridge makes it imperative that condition assessment criteria and methods, either by analysis or by testing, be tied in a rational and quantitative fashion to public safety, function, and economics.

Condition assessment and safety verification of existing bridges, as well as decisions as to whether posting is required, are addressed through analysis, load testing, or a combination of methods. Bridge rating through structural analysis is by far

the most common and economical procedure for rating existing bridges. Load testing may be indicated when analysis produces an unsatisfactory result or when the analysis cannot be completed due to lack of design documentation, information, or the presence of deterioration. The customary rating process allows ratings to be determined through either the allowable stress method or the load factor method.

A third rating procedure found in the *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges* is keyed to the new American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) method. The LRFR method is being introduced to the bridge maintenance community, and some states are beginning to use it in developing their bridge ratings. These rating methods may lead to different capacities and posted limits for the same bridge, a situation that cannot be justified from a professional engineering viewpoint and that carries serious implications with regard to the safety of the public and the economic well-being of businesses and individuals who may be affected by bridge postings or closures.

Inspection and Preventative Maintenance

The National Bridge Inspection Standards (NBIS), which were implemented in the 1970s, established a single, unified method of collecting data on the nation's public highway bridges. In the United States, these data are submitted annually by state Departments of Transportation (DOTs) to the FHWA, which compiles them within the National Bridge Inventory database. The NBIS have enabled the FHWA and state DOTs to monitor bridge condition and performance nationally on a consistent basis, identify bridge needs, define criteria of project eligibility for federal bridge funding, and thereby promote public safety through better stewardship of bridge assets.

Preventative bridge maintenance is defined as a planned strategy of cost-effective treatments applied at the proper time to preserve and extend the useful life of a bridge. Transportation Asset Management is driven by policy and performance and considers alternatives and trade-offs, evaluating competing projects and services based on cost-effectiveness and anticipated impact on system performance. As such it employs systematic, consistent

business processes and decision criteria and makes good use of information and analytic procedures.

In order to maintain and repair bridges within limited budgets in the United States, DOTs are establishing procedures for early detection of problems, timely repair, good preventative maintenance routines, and consideration of long-term effectiveness of dollars spent. The AASHTO bridge management software, Pontis, can be used to inventory elements of a bridge, run deterioration and cost models to determine long-term preservation policies, determine preservation needs and schedules, and provide network-level performance measures.

European models have gone further in incorporating environmental aspects. The LIFECON Life-Cycle Management System (LMS) is a European model of a predictive and integrated LMS for concrete infrastructures, on both a short-term and a long-term basis, developed to facilitate decision making. The system is divided into three levels of structural hierarchy: component and module, object, and network, with component- and module-level systems that address structural components such as beams and columns and their combinations in modules.

The object-level system deals with complete structures or buildings. The network-level system treats networks of objects such as stocks of bridges or buildings. Besides bridge structure condition and urgency of repair, the life cycle costs, user costs, minimum requirements of structural performance, structural risks, traffic and other operational requirements, aesthetics, environmental risks, and ecological pressures can be taken into account for multiple-attribute planning on all hierarchical levels of the system.

The life cycle analysis and optimization module involves the data applications for studying the economy of the life cycle and cost-effectiveness of optional maintenance, repair, and rehabilitation strategies. Alternative strategies are compared as life cycle activity profiles over a defined time frame. The purpose of life cycle analyses is to find the optimal activity profiles to reach the targets.

In January 2002, FHWA announced that Highway Bridge Replacement and Rehabilitation Program (HBRRP) funds can be used to perform preventive maintenance on highway bridges. Preventive maintenance activities eligible for funding include sealing or replacing leaking joints,

applying deck overlays that will significantly increase the service life of the deck, painting the structural steel, and applying electrochemical chloride extraction treatments to decks and substructure elements. FHWA is currently in the process of clarifying language and restructuring the NBIS. Proposed changes will reorganize the standards into a more logical sequence and make them easier to understand for inspectors and state and federal highway administrators.

Replacement or Rehabilitation

Decisions for replacement or rehabilitation are based on many factors, including the structural condition, the benefit of extending the remaining service life of the structure resulting from repairing the deficient structural components, the repair cost, and the traffic disruption associated with lane closures, among others. The choice of the retrofitting technique is based on the condition severity of the deficient structural components. Retrofitting techniques range from strengthening deficient components to replacing the whole structure. Common retrofitting or strengthening techniques include the use of steel jackets, fiber-reinforced polymers (FRP) and composites, bridge deck overlays, external prestressing, and shotcrete application.

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See Also: Bridge Design; Bridges, Condition of; Construction Management; Highway Construction and Maintenance; Transit Management and Operations.

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Bridges, Condition of

The American Society of Civil Engineers gave the nation's bridges a C+ in its 2013 report on America's infrastructure, up a fraction from the C that bridges received in the 2009 report. Yet with one in nine of the 607,380 bridges in the United States rated as structurally deficient and a shortfall of nearly \$8 billion annually in meeting the estimate given by the Federal Highway Administration (FHWA) for eliminating the deficient backlog by 2028, progress is at best modest.

Meanwhile, each day Americans take 200 million trips across deficient bridges in the 102 largest metropolitan regions. According to the lobbyist group Transportation for America, nearly a third of the country's bridges are more than 50 years old. By 2030, over half of existing bridges will be at the end of their design life.

Forty states decreased the percentage of deficient bridges from 1989 to 2008. Nationally, the number fell from 37.8 percent of all bridges in 1989 to 23.7 percent in 2008. But in 2008 all states combined spent \$8 billion, or a mere 13 percent of federal transportation funds, on repair and rehabilitation of bridges. Federal estimates to eliminate the backlog of needed repairs for 2008 was \$61.4 billion. Despite the billions spent, the number of vehicles traveling

across bridges classified as structurally deficient declined only 2 percent between 1992 and 2010.

National Bridge Inspection Standards

The National Bridge Inspection Standards were developed as a result of the Federal Aid Highway Act of 1968. The standards went into effect for all public bridges on federal highways in 1972, and thereafter routine inspections were mandated at least once every two years. In 1978, the inventory was extended to include all public bridges greater than 20 feet. The standards were adopted by all state transportation departments.

Inspectors categorize bridges that rank as less than 5 on a 9-point scale as structurally deficient, functionally obsolete, or fracture critical. The deck (riding surface), the superstructure (main supporting element of the deck, usually beams, girders, trusses, etc.), and the substructure (supports to hold up the superstructure and deck, usually abutments and piers) are rated on a scale from zero (closed to traffic) to 9 (excellent condition). A bridge receives a structurally deficient rating if any one of its main elements is rated 4 (meets minimum tolerable limits to be left in place as is) or less. States are quick to assure the public that structurally deficient bridges are not unsafe. The label *structurally deficient* is intended to sound an early warning that making repairs or building a replacement should become a priority. Speed or weight restrictions may be placed on the functionally deficient bridge.

Functionally obsolete bridges are those built to earlier standards that fail to meet current minimum federal requirements. These bridges are not automatically rated as structurally deficient, nor are they inherently unsafe. Functionally obsolete bridges include those that have substandard features, such as narrow lanes, narrow shoulders, poor approach alignment, or inadequate vertical under clearance. The Chesapeake Bay Bridge in Annapolis, Maryland, built in 1951, received one 5 (fair) and two 6s (satisfactory) in its 2011 inspection, but it is considered functionally obsolete.

A fracture critical bridge lacks redundancy. It typically has a steel superstructure with load (tension)-carrying members arranged in such a manner that if one fails, the bridge could collapse. The classification of “fracture critical” does not mean the bridge is inherently unsafe. About 18,000 bridges across the country have been deemed

fracture critical. The most famous fracture critical bridge is the I-35W Mississippi River Bridge, an eight-lane bridge in Minneapolis, Minnesota, that collapsed during the evening rush hour on August 1, 2007, killing 13 and injuring 145.

About 140,000 cars and trucks crossed that 40-year-old bridge daily, the same number that cross the 57-year-old, seven-lane Tappan Zee Bridge that connects the northern suburban counties of New York City. A new \$3.1 billion replacement bridge is scheduled to open April 3, 2018. The Pulaski Skyway between Newark and Jersey City, which was built in 1932, is scheduled for a \$1 billion rehabilitation beginning in 2014.

Workload for the States

Although states depend upon federal funds channeled through the Highway Trust Fund for a substantial portion of monies used to maintain and repair bridges, the greater portion of funds must come from state and local budgets. State governments finance these projects through taxes and fees that vary from state to state. Just as the federal motor fuel excise tax of 18.4 cents per gallon of gasoline (unchanged since 1993) provides the major source of funding for federal investment in the maintenance and repair of the nation's bridges, gasoline taxes levied by the state provide the major source of funding at the state level. State gasoline tax rates range from a low of 8 cents per gallon in Alaska and Georgia to a high of 38.16 cents in California, with an average of 23.47 cents per gallon.

Pennsylvania has the most deteriorating bridges. Of the state's 25,000 bridges, 26.5 percent are deficient. For fiscal year 2012–13, Pennsylvania invested a total of \$4.4 billion in its highways and bridges: \$2.8 billion (64 percent) in state funds and \$1.6 billion in federal funds. As of June 2012, the state had 4,774 deficient bridges, the lowest since before 1998. Another 600 bridges should be repaired by 2014. Federal stimulus dollars provided through the American Recovery and Reinvestment Act enabled Pennsylvania to improve at this rate, but to reach the national average of 11.5 percent, the state must repair 400 bridges each year through 2033. But the federal stimulus package has ended, and the state has a budget deficit.

Pennsylvania's bridge problems may be the most severe, but the state's problems are not unique. Twenty-two other states have a higher percentage

of deficient bridges than the national average of 11.5 percent. The five states with the worst bridge conditions all exceed a 20 percent share of structurally deficient bridges. With Americans driving more fuel-efficient cars and buying less gas because of higher gas prices, state revenue from fuel taxes is likely to continue to decline. At the same time revenue is declining, costs of labor and such essential materials as steel, asphalt, and concrete have all risen by at least 50 percent.

A Bleak Future

A boom in bridge building coincided with the baby boom in the United States from the mid-1950s to the mid-1970s. These bridges are all aging, and many of them are already reaching the end of their design life, an estimated 50 years. Many bridges support a greater traffic load than their designers imagined. According to the American Association of State Highway and Transportation Officials

(AASHTO), American bridges bear more than 3 trillion vehicle miles (4.8 trillion vehicle kilometers) of travel each year, and trucks contribute 223 billion vehicle miles (359 billion vehicle kilometers) of that total. When states are unable to meet the need for bridge maintenance, their only choice is to limit loads and close bridges. These actions increase traffic on other bridges, which increases the rate at which they will need repairs and multiplies traffic congestion, particularly in urban areas.

An AASHTO report released in 2008, representing state departments of transportation, concluded that federal, state, and local governments will have to increase transportation investment to preserve resources and meet future needs. Central to the AASHTO plan is implementation of systematic, long-term maintenance programs for existing bridge infrastructure. The group also sees as essential the consideration of a variety of financial options, including tolls, taxes, user fees, and bonds, as well as



Partially submerged cars in the Mississippi River beside the remnants of the collapsed I-35W bridge in Minneapolis, Minnesota, on August 5, 2007. The collapse of the fracture-critical steel truss arch bridge four days earlier during the evening rush hour killed 13 people. In 2013, one in nine of the 607,380 bridges in the United States were found to be structurally deficient, resulting in American drivers making a total of 200 million trips per day across deficient bridges in the 102 largest metropolitan regions.

other forms of private investment. Increased public awareness and a strong commitment to research and innovation are also essential.

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See Also: American Association of State Highway Transportation Officials; Bridge Design; Bridge Maintenance, Repair, and Replacement; Highway Construction and Maintenance; Highway Finance.

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Bureau of Budget Circular A-95

Federalism has been a central political issue throughout the history of the United States, beginning with the replacement of the Articles of Confederation by the Constitution. The balancing of federal–state and state–local governmental authority and responsibility has continued to coevolve with changes in our population, economy, and political parties. The first half of the 20th century, which included two world wars and the Great Depression, saw the steady growth of the federal government. Political scientists have called federalism during this period "cooperative." The creation of the Federal Aid Road Act of 1916 is a prime example. All subsequent federal transportation-related legislation and programs have necessarily addressed the centralization–decentralization aspects of funding and decision making. The U.S. Bureau of Budget's Circular A-95 played a central role in framing the

federalism aspects of transportation planning and program implementation during the transformative decade of the 1970s. Collaborative decision-making lessons from this experiment continue to inform transportation policy today.

Post World War II, Congress embarked on an ambitious set of initiatives to generate a reinvigorated peacetime economy. Included were the Interstate Highway System, and urban renewal. The former sent federal aid to rural-oriented state highway departments that were charged with locating, constructing, and operating an entirely new class of major facilities throughout their state, including dense urban centers and their rapidly changing suburbs. In contrast, urban renewal sent federal funds directly to single-purpose, nonelected local agencies that had been created specifically to administer this program of acquiring and clearing large structurally deficient areas for transfer to private developers. Infrastructure and land use are tightly coupled systems. For half a century, states had delegated plan-based land use control to its individual local governments. In contrast, these and other new federal programs generated regional zones of change and conflict that transcended municipal boundaries.

The Dwight Eisenhower administration was deeply concerned about the scope and direction of these unintended programmatic effects and worked with Congress to create in 1959 the Advisory Commission on Intergovernmental Relations (ACIR). It was a "permanent organization" with members appointed from Congress, the executive branch, governors, state legislatures, counties, cities, and citizens that worked with a small professional staff to analyze and recommend new directions in federalism.

The 1960s was a volatile decade. Cities were being bulldozed, race riots broke out, and suburban sprawl accelerated, all within the broader context of the Vietnam War controversy over misuse of federal power. Of particular concern to publics and policy makers were metropolitan areas. In previous decades, the decennial U.S. Census of Population and Housing had differentiated between "rural" and "urban" areas to provide guidance to congressional programs. By 1950, "urban areas" were defined as having a population over 50,000. The 1960 census included new statistical sample questions on location of work and mode of transportation. These

were used to designate Standard Metropolitan Statistical Areas (SMSAs), which consisted of central urban areas and adjacent, trip-to-work related counties. This census revealed that two-thirds of the nation now lived and worked in metropolitan areas.

Three laws from this period built directly upon the ACIR's initial reports. Together these laws represent the move toward "creative federalism." The 1962 Federal Aid Highway Act included the "3-C" requirement of continuing, comprehensive, cooperative planning in all census-designated urban areas. "Comprehensive" included existing and future land use, which was basis for the new traffic modeling approaches. "Cooperative" meant the involvement of federal, state, and local agencies and elected officials.

Congress passed the Demonstration Cities and Metropolitan Development Act in 1966, commonly known as "Model Cities." Its findings included recognition that the complexity and fragmentation of local governments and special districts in rapidly growing metropolitan areas was hindering the effective use of federal-aid programs. It mandated that all local and state applications for grants and loans for transportation facilities, airports, water and sewer, and other development projects within a metropolitan area, were to be reviewed for consistency with area-wide development plan and policies by a regional planning agency composed of an area-wide government (such as a Council of Government), or a Regional Planning Board composed of elected local governments. This was an explicit top-down mandate by the federal government to the states about how they were to internally organize themselves in metropolitan areas. Although it could not be enforced constitutionally, no state had an interest in cutting off federal programmatic aid. At the federal level, "Model Cities" was an attempt to reinvent the Department of Housing and Urban Development's (HUD) problematic Urban Renewal Program. The HUD administrator was designated to coordinate metropolitan development programs within the federal agencies.

To implement this law the Bureau of Budget (now the Office of Management and Budget) issued Circular A-82. A small but important grassroots movement toward metropolitan facility management was already under way in some states that had created regional planning commissions (RPCs) or

Councils of Government (COGs) to address specific emergent metropolitan issues, such as water supply, commuter rail financing, and jetport siting. The Twin Cities of Minneapolis and St. Paul, Minnesota, have often been used as a model from this period. These organizations were funded in part through the 1954 Housing Act, which identified area-wide planning in metropolitan regions as an important complement to municipal planning.

A-82 encompassed 32 physical development-related programs that had to be reviewed for consistency with an area-wide development plan. Where they already existed, states typically designated RPCs and COGs for the clearinghouse function. Some of the latter, such as the Denver Regional Council of Governments, were also responsible for 3-C transportation planning. Where no RPCs existed, they were created. Some RPCs evolved into COGs in order to meet the law's "composed of elected officials" requirement.

Circular A-95

Implementation of A-82 was just starting up when Congress passed the Intergovernmental Cooperation Act of 1968. This was a comprehensive piece of fiscal management legislation aimed at providing governors with better information for planning and managing the increasing role of all federal aid programs within their states and for improving interagency coordination between the federal departments. To implement this law, the Bureau of Budget issued Circular A-95 in 1969, which superseded A-82. Added to A-82's metropolitan regional clearing house function was the requirement for regional clearinghouses to review programmatic grant programs in all nonmetropolitan areas.

In addition, a new tier of state clearinghouses was required to receive all grant requests made by their agencies and units of local government. Over the next decade, the Bureau of Budget expanded the number and scope of programs required to undergo review. Starting with 51 programs, A-95 was increased to 100 programs in 1971 primarily with the addition of new health, job, and social services congressional initiatives. By early 1980 it had reached 259 programs.

Functionally, A-95 was designed as an "early warning" information system between five sets of institutional actors: the White House Bureau of Budget, regional clearinghouses, state clearinghouses,

local and state government applicants for federal programmatic grants, and the federal agencies administering grants. Information flow was structured by the Project Notification and Review System (PNRS).

Applicants for designated grant programs sent a notice of intent (NOI) including location information and a summary description to the state and regional clearinghouses. Clearinghouses had 30 days to determine whether there might be conflicts with state or area-wide policies and plans. This often involved forwarding the NOI to appropriate local governments and agencies. If no issues were identified, the applicant was cleared to submit their federal grant application. If potential issues were identified and not resolved, the applicant was required to submit the entire application for detailed review and comment to the clearinghouses. Within 30 days, the application and clearinghouse comments were sent to the federal grant agency. Granting agencies then processed the applications, including consideration of comments. Applicants and clearinghouses were notified of the decisions.

In his 1981 inaugural address President Ronald Reagan stated: "The federal government did not create the states; the states created the federal government." In 1982 he issued Executive Order 12372, Intergovernmental Review of Federal Programs. This executive order was part of his larger administrative reform initiative "devolution," the reduction of federal authority by transfer to the states. It revoked A-95, eliminating the mandate for state and regional review as a requirement for federal grants. It encouraged states to establish their own approaches for coordinating local-regional-state-wide interests. Over the next few years, many of the programs that had been included under A-95 were either eliminated or consolidated into "block grants" that gave state and local governments considerable expenditure flexibility. Today, the Federal Office of Management and Budget maintains a list of "official state agencies" designated by governors, the Single Point of Contact (SPOC). Federal program granting agencies are required to coordinate with these state units in grant application processing. Less than half the states currently participate in SPOC.

Controversies and Critiques

From a transportation perspective, the A-95 program was controversial throughout its decade-long

existence. Issues may be grouped into four categories: institutional capacity, federal agency "buy-in," obsolescence, and substate complexity. Capacity encompasses the professional staff, budgets, and information resources of the regional clearinghouses and the orientation to A-95 from the clearinghouse leadership. The short-lived A-82 metropolitan-based clearinghouses were conceptually a good fit with the prevailing administrative approach of applying rational planning to the disjointed physical development programs and jurisdictions to be reviewed. However, unlike municipal planning, which had evolved over a half century that was tightly coupled to elected legislatures and program implementation, there were no standards or guidelines for metropolitan plans. 3C transportation planners often had to work with a patchwork of conflicting existing municipal plans and their more generalized regional growth trend forecasts. For many of the clearinghouses, their regional development plans were in process, neither completed nor adopted, and the plans tended to be quite general. This raised serious questions regarding the basis for plan conformity review.

A particularly volatile topic of concern involved state highway departments implementing the Interstate Highway program in metropolitan areas. Prior to A-95, the Bureau of Public Roads interpreted the 3C "cooperative" requirement as allowing states to negotiate agreements directly with local officials, thereby bypassing the regional planning organizations. The A-95 process posed a potential "veto" by a regional council. Although A-95 called for a single metropolitan clearinghouse, the large range of programs involved, from sewers to transit to civil rights to crime, was a poor fit with both the interests and the technical capacity of transportation-focused planning organizations.

The 1970s are known as the "environmental decade" for sweeping new federal legislation, starting with the National Environmental Policy Act of 1970 (NEPA). Initially, this law's mandate for environmental impact analyses was highly contested in the courts, but by the time of the issuance of the NEPA regulations in 1978 the Supreme Court had upheld its procedural mandate for all federal agencies. The NEPA regulations specified a comprehensive multidisciplinary, federal-state, local, and public collaborative analysis and review process for all federally aided transportation projects. The 1973 Federal Aid

Highway Act created Metropolitan Planning Organizations (MPOs) funded from the Highway Trust Fund. MPOs were required to have representation by local elected officials as well as transportation-related agencies. The OMB subsequently revised A-95 to allow the MPOs to provide the A-95 review for transportation projects. NEPA coupled with the MPOs had essentially rendered A-95 obsolete.

The A-95 process was also critiqued from the perspective of wasteful, ineffective paperwork. There were no substantive analyses of the program's functionality or cost-effectiveness. Clearinghouses faced a fundamental challenge of operating a distributed information and analysis mandate within 30-day time limits in the predigital era. There was no word processing, Internet, or geographical information systems (GIS). Anecdotal evidence consistently reflected that the reviews and comments were necessarily superficial. The OMB had required the creation of clearinghouses and the review of grants for consistency with plans, but it did not require functional plans. States were generally ambivalent on this issue. There was no federal or independent analysis of whether A-95 had any influence on the grants. In many regions, the prime operational objective of the clearinghouse was to maximize the flow of federal aid.

In this period, the federal government was not able to assess an administrative program such as A-95. Both the Bureau of the Budget and the General Accounting Office (GAO) were primarily focused on tracking monetary flows for waste or misuse. Today the OMB and the General Accountability Office are deeply involved in assessing the outcomes effectiveness of federal programs. This is done in collaboration with the agencies. All DOT programs are analyzed with OMB as part of the continuing federal budget process. The GAO undertakes specific analyses at the request of a member of Congress concerned about the performance of a particular program. Their reports are public information.

Conclusion

Congressional funding for the ACIR was eliminated in 1996 after a decade of slow decline in both studies and influence. The A-95 approach has been interpreted by some as a shallow bureaucratic one-size-fits-all example of how not to handle the rich diversity of regions within the United States. Others, particularly from the perspective of rural areas,

have seen it as a flawed but necessary transitional approach in a period of rapid change that supplied impetus for regional collaboration. The underlying dynamics of federalism, particularly for metropolitan transportation systems, is today an active arena of innovation and experimentation. The evolution of multimodal transportation funding legislation; the increased roles of MPOs, including project programming, public participation, and Clean Air Act coordination; and "smart growth" demonstration initiatives partnering with the EPA are all consistent with the historically important role of states and localities as the "laboratories of democracy."

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See Also: Interstate Highway System; Metropolitan Planning Organizations; National Environmental Policy Act; 3-C Planning Process.

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Bureau of Public Roads

At the end of the 19th century, traffic on most American roads consisted of wagons, coaches, horses, bicycles, and pedestrians. However, the national government was beginning to recognize the need for federal involvement in building and maintaining roads and ensuring the safety of Americans who traveled those roads. In 1893, the

first national highway agency was established as the Office of Road Inquiry (ORI). The first head of ORI was General Roy Stone (1836–1905), an engineer and former officer in the Union army who was a strong believer in the need for improving public roads in the United States. His first annual budget was \$10,000. The name of the agency was changed to the Office of Public Roads in 1905 when it became part of the Department of Agriculture. In 1915 a third name change designated the agency as the Bureau of Public Roads.

Yet another name change occurred during the New Deal, and in 1939, the agency became the Public Roads Administration, operating under the auspices of the Federal Works Agency. By that time, the focus was shifting away from rural areas and toward urban areas where most transportation problems were surfacing. Officials at national, state, and local levels had all become concerned with traffic congestion, urban decay, and the loss of tax monies as Americans moved away from large cities.

When the Federal Works Agency was dismantled in 1949, the Public Works Administration reverted back to being the Bureau of Public Roads under Reorganized Plan No. 7 and became part of the Department of Commerce. When the Department of Transportation (USDOT) was established in 1966, the Bureau of Public Roads was folded into the USDOT, and its responsibilities were subsequently transferred to the newly established Federal Highway Administration (FHWA).

Early History

In 1905, the Division of Tests, which was part of the Bureau of Chemistry, was combined with the Office of Public Roads (OPR) in the Department of Agriculture. The combined agency retained the name Office of Public Roads. That same year, the U.S. Forest Service was created, and OPR immediately began providing professional services to the new agency. The OPR also continued to advise other federal agencies engaged in any aspect of road construction. In 1912, Congress passed the Agricultural Appropriations Act, which provided funds for constructing new roads and trails and improving those already existing on public lands. Another provision of the act appropriated funding for improving roads designated as “Postal Roads.” State and local governments were required to assist in the latter endeavor by providing matching funds. The

following year, Congress appropriated new funds to continue the project.

In 1916, Congress passed the Federal Aid Road Act, which established the Federal Aid Highway Program, officially recognizing the commitment of the national government to expanding the highway system within the United States. This meant that the federal government needed a professional corps of engineers within the Office of Public Roads to oversee the program. The following year, 10 district offices were established and charged with working with state and local governments to construct Post Roads. These regional offices also continued to work in partnership with the National Forest Service and state and local governments on surveying, constructing, and maintaining roads located within national forests. The Agriculture Appropriations act of 1919 renamed what had come to be called the Office of Public Roads and Rural Engineering, and the agency became the Bureau of Public Roads (BPR).

Expanding Responsibilities

In the 1920s, both Ford and General Motors were manufacturing cars that were taking to American highways. Under the leadership of Henry Ford (1863–1947), the Model T was the first choice for many families until Ford introduced the Model A in 1927. General Motors, on the other hand, provided greater choice, offering different models for different markets. GM manager Alfred P. Sloan, Jr., (1875–1966) was the first to conceive the benefits of a used-car market that allowed owners to trade in old cars and use the proceeds to buy more expensive vehicles. By the end of the decade, the American highway system had grown to 830,000 miles of paved roads, and the number of automobiles had climbed to 23 million.

In order to meet the needs of the expanding transportation sector, the national government was willing to commit considerable resources. Those resources consisted of providing financial assistance and technical knowledge, and sharing information. As the national agency charged with responsibility for overseeing highways, the Bureau of Public Roads was poised to play a major role in the development of the contemporary United States.

In 1921, Congress passed the Federal Highway Act, reauthorizing the existing highway program. The 1921 act was also designed to provide support



A 1990 view of the “Weeping Wall” roadside waterfalls on Going-to-the-Sun Road in Glacier National Park in Flathead County, Montana. The 51-mile scenic road was partly carved out of a mountainside. It was the first project to follow a 1925 Memorandum of Agreement for collaboration between the National Park Service and the Bureau of Public Roads.

to encourage transcontinental highway travel, encourage state and local communities to develop their own resources, and promote conservation and the development of national resources. Regional offices established under the act took on responsibilities for coordinating efforts within designated areas. The act also established a tax on motor fuels to be used to fund the activities of the Bureau of Public Roads, which had been assigned responsibility for constructing a national system of paved two-lane highways.

In 1924, Congress authorized major road construction within national parks, and the Bureau of Public Roads signed a Memorandum of Agreement pledging to work with the National Park Service on the project. By 1926, Route 66, a major national highway connecting Chicago with Los Angeles, had been completed. To simplify matters, BPR designated roads running north to south with odd

numbers. Roads traveling from east to west were assigned even numbers. By the time the 1920s drew to a close, some \$200 million had been spent on American highways each year of the decade.

Some of the early projects conducted by the Bureau of Public Roads still stand as permanent testaments to the agency's contributions to developing American highways. In 1928, the BPR was assigned responsibility for locating, designing, and building the Mount Vernon Memorial Parkway. The completion date was set for 1932 in order to celebrate the 200th anniversary of the birth of George Washington, the nation's first president. The parkway ran along the Potomac River and was designed to maintain the beauty of the area by following the contours of the land. In the 21st century, that parkway is part of the George Washington Memorial Parkway, and it is still considered one of the Bureau of Public Roads' major accomplishments. Other

BPR contributions can be found in national parks located throughout the United States, including Grand Canyon, Mount Rainier, Rocky Mountain, Sequoia, Yellowstone, Zion, Great Smoky Mountain, Shenandoah, and Everglades.

The work of the Bureau of Public Roads also extended into U.S. territories. For instance, in 1933 the BPR began working with the National Park Service and local officials to design and build Hawaii's Haleakala Highway. Local officials depended heavily on the technological knowledge of the BPR's engineers to design and construct the road without destroying the natural environment of Haleakala National Park, which connects the islands of Hawaii and Maui. The park was established on a dormant crater and was one of the most isolated spots in the world at the time. After the highway was completed in 1935, it began drawing large numbers of tourists to the islands.

Shifting Priorities

During the early years of the Great Depression, which continued throughout the 1930s, the BPR was heavily involved in working with state and local governments to put Americans to work building roads under the New Deal's public works projects. In 1939, a Bureau of Public Roads report titled *Toll Roads and Free Roads* clarified the shift in focus to urban roads as the nation's attention turned to the issue of building a national highway system that would connect the country from coast to coast and from border to border. When the Bureau of Public Roads became the Public Roads Administration on July 1, 1939, under President Franklin D. Roosevelt, it continued to fulfill its ongoing responsibilities.

According to American legend, it was FDR who first articulated the notion of connecting the United States via a system of interstate highways. The legend credits Roosevelt with drawing three lines stretching north to west and another three lines traveling from north to south on a map and instructing the Bureau of Public Roads to turn those lines into six interstate highways. The validity of the legend is in doubt, according to highway historian Lee Mertz, but it is true that in Section 13 of the Federal Highway Act of 1938, Congress requested the head of the BPR to investigate the feasibility of building an interstate highway system.

Newspaper reports of the day also recorded Roosevelt's interest in building an interstate system.

The *Washington Post* suggested that he intended to fund the new highway program through a \$4.88 billion works program. Two years earlier, Roosevelt had expressed support for a proposed congressional bill designed to construct 10 transcontinental highways to serve as both a national defense mechanism and an economic stimulator.

After the agency became the Public Roads Administration (PRA) in 1939, its work as part of the Federal Works Agency involved working closely with the Department of the Interior and the U.S. Postal Service, providing advice on locations and furnishing technical expertise on road design and construction.

After the Japanese attacked Pearl Harbor on the morning of December 7, 1941, the United States was plunged into World War II. All existing projects were placed on hold as the PRA turned to assisting the military with defense projects. American highways came into heavy use during the war years because of the toll exacted by transporting troops and heavy military equipment. By the time the war ended in 1945, most American roads were in serious need of repair.

In 1944, Congress passed the Federal Aid Highway Act, which authorized the building of 40,000 miles of national highways. The Bureau of Public Roads was assigned a major role in the project, including responsibility for dispersing some \$125 million in funding. Those funds were not sufficient for completion of the project. Building a national highway system proved extremely costly for the poorest Americans, who were predominantly African American and immigrant. Those populations often witnessed the destruction of their homes as land was cleared for the national highway project.

Dreams to Reality

In 1949, the Public Roads Administration became part of the new General Services Administration and reverted to the name Bureau of Public Roads, working under the Department of Commerce. In 1956, the Federal Aid Highway Act called for reorganization within the BPR. The Federal Domain Division, which subsequently became the Federal Highway Projects Division, was charged with overseeing the construction of national highways. The postwar years were characterized by economic prosperity in the United States, and President Dwight D. Eisenhower was finally successful in convincing Congress to pass the Federal Aid

Highway Act of 1956, which provided sufficient funding for building the interstate highway system that FDR had envisioned.

The functions of the Bureau of Public Roads continued to evolve over time. By the 1960s, mass transportation was becoming increasingly important because of traffic congestion in large cities and concern over the environmental damage caused by burning fossil fuels. In 1966, the Department of Transportation Act established the Department of Transportation. On April 1, 1967, the Bureau of Public Roads was transferred to the DOT, and its responsibilities were assigned to the Federal Highway Administration (FHWA).

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See Also: Department of Transportation Act of 1966; Federal Aid Highway Program; Federal Aid Road Act of 1916; Federal Highway Administration; Interstate Highway System.

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Bus Capacity

Bus capacity is the total number of passengers a public transit bus may safely carry. This number is quantified by a factor known as the load ratio. This ratio is the total number of travelers a bus may facilitate, including seated and standing passengers. If a bus goes above this load ratio, it is considered overcrowded. However, just because individual buses or lines are overcrowded does not mean that the total system is running above, or even at, capacity. Even in cities with perpetually overcrowded lines, there are likely many lines that frequently run far under capacity. In fact, it is possible for a city bus line to run at under 50 percent capacity while certain lines are constantly overcrowded. Overcrowding on buses can cause problems, including passenger discomfort, difficult bus entries and exits, and exacerbation of delays. There are several issues that may cause this condition, including improper staffing, not enough buses, lack of funding, improper distribution of resources, or ineffective line placement. If these issues were resolved, it is possible that many overcrowding problems would be resolved.

Interpreting Load Ratios

The industry standard maximum load ratio is 1.25. If all seats are filled but there are no standees, the ratio is said to be at 1.00. If all seats are full and a number of people equal to 25 percent of the total seats are in standing positions, the bus is said to be at a ratio of 1.25. Thus, if a bus with 40 seats, has 50 people on it, the ratio is 1.25, the maximum available ratio.

The maximum allowable ratio is not a hard and fast rule. Depending on the situation, the maximum

ratio may go up or down. On highways or express lines, where the bus is expected to travel at a faster rate of speed, ratios are often kept at or around 1.00. This is because it is widely thought that these buses travel too fast to facilitate a significant number of standees. The load factor on a given line may also shift based on the time of day. This is done to facilitate a greater demand and keep wait times at bus stops tolerable.

Adjustment of the Maximum Ratio

While it may have been reasonable in previous eras, there is debate over whether the load ratio of 1.25 is still appropriate for today's modern buses. Since the present load ratio was established, the industry has transitioned from high-floor buses to low-floor models. Low-floor buses have been adopted by bus services nationwide due to their increased handicapped accessibility. Low-floor buses are designed with a minimal number of steps between one or more entrances and part or all of the passenger cabin. With this major adjustment, the design improves accessibility to handicapped, elderly, and otherwise infirm individuals. Low-floor buses are also capable of hydraulic lowering and other features that enable an improved experience for wheelchair users.

The load factor of 1.25 was adopted as an industry standard during a time when the standard bus had a high floor. Such high-floor buses were typically 40 feet long and had 47 seats. Today's buses are significantly lower than the previous high buses. The standard 40-foot low bus has 38 seats. Thus, to carry the same number of passengers as high buses, low buses must carry a greater number of standees. Additionally, standard low-floor buses require standing passengers to stand closer together by eliminating stair well and wheel standing spaces and adding wheelchair access spots. Considering the space constraints placed on standees on low-floor buses, industry experts have proposed that the load ratio be lowered to 1.20 for low-floor buses.

Solving Overcrowding

There are several potential methods that could be used to alleviate overcrowding on metropolitan buses. Many of these methods could stand on their own, but others are dependent on each other to see their full effect. At the most basic level, cities that face critical overcrowding need to either add

more buses to their fleets or review their existing lines. It could be that the lines within the city are inefficiently distributed; thus, if lines are put where they can be more effective, load factors would lower while total system capacity would rise. If lines are already at their most efficient, bus systems must purchase additional buses. Once fleets are expanded, the frequency of schedules may be increased, thus lowering capacity.

Additionally, if systems are able to invest in better buses, they could purchase models with greater capacity, those with prepay toll systems that would free up standing room in the front of the bus, or articulated buses that allow for additional standing room. Finally, if a fleet has enough vehicles to spare, it can create express routes or Bus Rapid Transit that can quickly and effectively transport passengers from high-traffic area to high-traffic area, thus alleviating load ratios in the rest of the system.

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See Also: Bus Design; Bus Rapid Transit; Bus Scheduling; Bus Systems, Local and Express; Buses; Busways and Reversible Bus Lanes; Mixed-Mode Transit Systems; Public Transit Employees and Labor Issues.

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Bus Design

A bus is an autonomous road vehicle designed to carry passengers and their personal effects. A bus driver steers the vehicle and determines the safe speed of operation on a particular road. A bus usually carries enough fuel or energy to be able to operate at least from one end of its route to the other without refueling. The exception to this is trolleybuses, which are powered from overhead electric cables.

Present-day motor buses have been developed progressively from horse-drawn omnibuses of the 19th century. This development includes motive power, wheels, suspension, speed, size, passenger comfort, and capacity. Operational developments have included the switch from two-man to one-person crews, and passengers buying tickets prior to making the bus journey.

During this time the motor car has been developed even more rapidly, and where once buses catered to a carless “captive” population, today in many countries most people have cars, which is their prime mode of travel. Buses are now used mostly by people without a car, or who cannot drive. In many countries various classes of people are issued free bus passes, for example, pensioners, disabled, and school children, who make up the majority of passengers.

Development

In 2012 some 193,000 buses were manufactured worldwide, with the top five countries (China, Brazil, South Korea, Russia, and Japan) producing 78 percent of them. In comparison, 21 million trucks were built worldwide. The importance of this is that bus production is not large enough in any country to support mass production as a single product vehicle. Bus costs are kept relatively low by using mass-produced parts from the truck industry, including engines, gearboxes, axles, suspension, and steering.

The motor bus development was accelerated by World War I, when lorries were used to carry supplies to war zones and buses carried soldiers. At the end of that war, many surplus buses and trucks were put into service for both urban and rural traffic. This first generation of buses was powered by gasoline engines and ran on solid-rubber tires. With the poor state of road surfaces, this gave a most uncomfortable ride compared to streetcars, that dominated urban transit at the time. Two

developments improved ride quality: first, tarmac (smooth) surfacing of roads, and second, the adoption of pneumatic tires.

World War II brought diesel engine reliability to the same level as gasoline engines with better fuel economy; this led to the rapid replacement of gasoline engines with diesel engines for buses.

Technology

The technology used for buses piggybacks on the mass truck market. In the last 30 years there has been a rapid change in the way buses are designed and operated. Historically, the bus engine and steering wheels were at the very front of the bus, with the entrance at the back or in the middle. This required a two-man crew—a driver and a conductor who collected the fares. Due to limitations of tires, these buses were small, carrying about 40 passengers, and in a number of countries also included an open-top upper deck, allowing about 50 passengers. These first buses weighed only about four tons.

As tire technology improved, buses got progressively longer, wider, and heavier. The economics of operation, especially in cities where fares are set politically, led to the adoption of one-man operation, requiring the driver to collect fares or check tickets. This led to both the steering wheels (forward control) and the engine being moved away from the front of the bus. Various alternative engine positions were tried—vertical mid on one side, horizontal under the floor, and vertical across the back of the bus—all with more complicated drive lines and gearbox positions.

As buses got heavier, carrying more passengers, manual steering became physically difficult, and power steering was introduced. In the same vein, automatic gearboxes replaced manual in an attempt to give passengers more comfortable and consistent riding during acceleration, and power-operated brakes offered more consistent stopping.

During the oil crisis of the 1970s various methods to reduce fuel consumption were tried, including flywheels to store energy from braking and release it for acceleration. Such flywheels need to revolve at above 100,000 rpm to store significant energy and could only be mounted horizontally mid-floor to minimize the gyroscopic effect on steering.

The quest for improved fuel consumption continues, and while the compression/ignition engine remains the backbone of bus drive units, different fuels, including compressed natural gas (CNG),

liquefied petroleum gas (LPG), and biodiesel (from crops and municipal waste) are being tried in different cities, with varying results. Because none of these alternative fuels have the same energy density as diesel oil, these other systems do not offer the same energy efficiency but may be cheaper because of local tax or subsidy regimes.

Finally, new generations of hybrid systems are being tried, with the engine driving a generator, powering electric motors attached to the drive wheels, with batteries for storage/release of braking power. In total, these alternative power systems are heavier than straight diesel drive, even though a gearbox is not needed. Making a direct energy-efficiency comparison is therefore more difficult, especially if the heavier drive means a smaller passenger capacity.

Types

Not only has the power train of buses developed significantly, so too has the form of buses. The rigid single- or double-deck bus on two axles, usually 40 feet (12 meters) long weighing about 10 tons, has developed into longer rigid three-axle buses, with two drive axles and one steering (15 tons). The ultimate is the four-axle 50-foot/15-meter rigid double-decker, with two steering and two drive axles (20 tons). Such long rigid buses can only be used on bus routes that are almost straight, since turning corners is difficult. The single- or double-deck variations reflect local operating conditions and whether most passengers expect to sit for the bus journey.

Double-deck buses need stairs between the lower and upper decks. Originally, a single stair was at the back next to the loading platform. When boarding was transferred to the front of the bus, the stairs were moved, usually to behind the driver, sometimes ascending from front to back, but mostly the other way round, because on hard braking, passengers on the stairs are thrown against the stairs rather than down them. As double decks got larger, many operators adopted two sets of stairs, one for ascending and the other for descending, to allow nonconflicting passenger flow through the bus. While double-deck buses have many more seats than single-deck buses, the stairs reduce the available and useful space on the lower deck, which is most accessible to passengers with mobility impairments.

Articulated buses are two-axle rigid buses pulling a single-axle trailer, linked so that passengers

can walk safely between the two parts. The first generation of articulated buses had the engine mounted under the floor of the front section. Later, as lower floor designs emerged, the engine was moved to be mounted vertically at the rear of the trailer section, driving the single trailer axle, or sometimes both the trailer axle and the front-section rear axle. Driving just the trailer axle requires that special attention be paid to the articulation mechanism to prevent the trailer section from jackknifing. These articulated buses are usually 60 feet (18 meters) long and 16 tons and have almost the same maneuverability as a rigid bus but with a wider swept path.

More recently, two trailer sections now follow a lead rigid bus, all linked internally as one vehicle 75 feet (19 meters) long and 20 tons, but unless one or both of the trailer axles steer, this double-articulated bus has a very wide swept path on turning, restricting it to nearly straight routes. For all varieties of articulated buses, routes and depots are needed where the buses are able to travel forward, because reversing is difficult, and even with anti-jackknife safeguards buses can be seriously damaged when trying to reverse.

The adoption of doors on buses to replace a rear open platform led to the development of an operating mechanism and then to revised arrangements. On buses with a two-man crew, the conductor operated the door. As one-man operation became universal, the driver took over responsibility for the door. Most buses have two or more doors, depending on the fare collection system. Where an off-bus revenue system is used, doors can be used for both boarding and alighting.

On single-deck rigid buses, three doors are the norm—one at the front, one in the middle, and one at the back—to ensure even loading at peak times. On articulated buses, there is a door in each trailer section. For those bus systems where drivers still collect or check fares, all passengers board at the front, and in many cases alight at the front, with only a single door provided. This means that the time spent at bus stops is a significant part of the scheduled time, leading to a slow operating speed.

At present, with the size of wheels, engine, gearbox, and transmission, it is not possible to build a bus with a significant “low floor” area. Normally, a compromise is a slightly higher floor with raised curbs and a retractable “bridge” to provide stepless

boarding and alighting of passengers, for example, in wheelchairs, though more frequently used by parents with baby carriages. The deployment of the “bridge” increases the stop time and therefore the bus journey time.

Operation

Bus operation neatly falls into two parts: route structure and revenue collection. Some bus networks attempt to provide service on many origin–destination routes without the need for changing. Inevitably, this means low-frequency services and therefore attracts those who have no alternative travel options, except taxis. Those with cars value their time too highly to depend on infrequent bus service. In other cities, less complex “few to few” routes are run at higher frequencies, typically five-minute intervals. “Turn up and go” bus services attract more of those with travel options, especially if the routes target the most heavily used travel corridors. Such networks also provide for “many to many” options by means of interchanging, and purpose-designed interchanges can make this an attractive option, especially when coupled with high-frequency connecting services. In cities where buses literally provide for a very small proportion of travel, less than 5 percent of all local travel, as in many U.S. cities, then infrequent routes can be timetabled to meet simultaneously at a downtown interchange station, to enable “many to many” journeys to be made using a “few to few” route network.

This leads to revenue collection. Those networks where a separate ticket is required for each journey have fewer interchange trips, since there is a financial penalty on interchange. An increasing number of cities now sell access to the whole network rather than to individual routes. This means that interchange trips can be made without financial penalty and, indeed, encourage the maximization of network use, on the basis that additional bus trips have a zero marginal price to the passenger. For the operator, such additional trips, provided there is spare capacity, also have nearly a zero marginal cost of provision. In many cities bus fares are set politically, without reference to market conditions or revenue maximization. This requires subsidies to cover the difference between low revenue and the high cost of providing a politically determined network. This also means that

the operator’s role is effectively that of a network manager, with few incentives to maximize either ridership or revenue.

Passenger Facilities

Many bus systems are based on the majority of passengers standing on most trips made. Where passengers have no alternative travel options this is accepted, even though it can be uncomfortable to stand in a swaying and jerking bus. Where passengers have travel options or journeys are relatively long, most passengers expect to sit. Maximizing the number of seats then becomes a key feature of bus design.

In many cities vandalism seems to be a factor in providing and maintaining seats, so hard wooden or plastic vandal-proof seats are often the norm. This is not an attractive passenger offer, even though vandal-resistant textiles are available. For safety reasons, few buses have sideways mounted seats, because in emergency braking situations passengers can be catapulted toward the front of the bus, with exposure to injury. So seats are usually forward facing, and sometimes rearward.

Similarly, hand holds, steps onto the bus, and other requirements can make boarding and alighting easier or more attractive, especially for the elderly or infirm, who in many cities make up a significant proportion of ridership. How can passenger “luggage,” such as shopping bags or baby carriages, be accommodated? In some cities hooks on the front of the bus allow baby carriages and bikes to be carried, although at the cost of extended stop time while the item is hooked on or taken off, with driver supervision.

Marketing and Presentation

Compared to other consumer products, the marketing budget of most bus services is trivial, and compared to motoring, gas, and other driving products virtually nonexistent. In most cities most residents are unaware of what bus services are available and where buses operate. Very few bus companies collect passenger or nonpassenger views about buses before new buses are ordered. Usually new buses are purchased to satisfy supply-side issues, with perhaps a token gesture to the needs of passengers.

This similarly applies to the livery of buses, often chosen by committees of politicians with little or

no reference to passengers. Some bus manufacturers conduct market research on passenger expectations but usually in the locale near the plant rather than in the city of the purchasing agency. While better marketing and advertising can raise awareness of bus services, this is no guarantee that use will increase.

Safety and Passenger Comfort

Most countries have minimum standards for the design and construction of buses, principally to ensure the safety of passengers and operating staff. Rarely are passengers consulted about the internal design or appointment of new or refurbished buses in relation to ease of boarding and alighting, comfort of seats, or the ease of getting in and out, whether seats should be bench or individual, hand holds, internal décor, etc. Fold-down seats can be used to provide more seating off peak, when generally less mobile passengers travel, and in the peak folded away to increase the space for standing passengers. Rarely is this discussed with passengers.

If the bus industry is to regain market share, consumer preference studies at least as detailed as those used by car manufacturers are needed. As most bus services are publicly funded, this would seem to be an unlikely line of development. So can bus services only look forward to a regime of managed decline, within the budget constraints of public funding bodies?

Economic Issues

If car users can be persuaded to ride buses along busy urban roads instead of driving, there would be less congestion and less environmental impacts like pollution and noise. Buses make better use of road space; typically a bus can carry 60 passengers, occupying the same space as three cars, which on average carry only four passengers, with a maximum of 12. Freed-up road space could be reused for other, more socially beneficial uses, like trees, cycle tracks, etc. In democratic societies such transfers from car to bus cannot be ordered. Even financial inducements like downtown parking charges, congestion charges, road tolls, or special car licenses are not enough to make a meaningful switch achievable. In this reorganizing of the urban economy, bus design is a relatively cosmetic issue compared to the more fundamental one of citizens' views of the role of buses.

Energy Issues

Buses are heavy users of fuel, although more efficient than the equivalent number of cars needed to carry the same passengers. However, this analysis is only valid if buses carry passengers. Empty buses are wasteful users of fuel. This is one reason why some operators use minibuses for periods with low passenger demand. As oil becomes too expensive to burn, fueling buses will be a critical issue, which even if the state operates a rationing system favoring buses, will still result in fuel becoming a major operating cost.

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See Also: Bus Capacity; Bus Design for Accessibility; Bus Rapid Transit; Bus Rapid Transit, Design and Engineering of; Bus Routes; Bus Scheduling; Bus Stops/Shelters; Buses; Handicapped Access; Trolleybuses.

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Bus Design for Accessibility

Transit users with special mobility needs could face transport-related social exclusion if a universal design philosophy is not fully embraced for improving the bus passenger experience as a whole. “Universal design” refers to providing transport in terms of vehicles, infrastructure and services that would efficiently provide people of diverse mobility requirements with equal opportunities to access their desired destinations. Therefore, accessible bus design, besides fulfilling the basic bus user requirements, needs to accommodate wheelchair users, people with visual and hearing impairments, cognitive-challenged people, people walking with difficulty using some form of aid such as a cane or walking frame, older people, parents with strollers, children, pregnant women, people with temporary accident injuries, even people carrying heavy baggage.

Inclusive Bus Design

For many years, buses have been designed to cater mostly, if not solely, to the needs of the average road user, who usually is a younger, physically and mentally competent traveler commuting to and from work. This is not the case anymore, as providing public transit accessibility for people with reduced mobility is legitimately enforced almost everywhere in the world.

The most important principle toward providing a bus experience that fulfills the criteria of inclusive design is to offer all necessary means of access so that a mobility-challenged user can easily enter and exit the vehicle. There are two types of gaps relevant to bus accessibility that need to be bridged so that even wheelchair users, who are the people facing the greatest barriers when accessing or alighting a bus, could be satisfied: (1) the vertical gap, which is the difference in height between the vehicle floor and the pavement at the bus stop, and (2) the horizontal gap, which is the horizontal distance between the edge of the pavement and the vehicle floor.

Conventional, or high-floor buses, can provide boarding-assisted access through use of wheelchair lifts. These elevating mechanisms have been employed in the past, but the considerable cost and the unreliability of their use made this choice unattractive for bus fleets, especially in Europe. Today,



The interior of a special bus designed to accommodate multiple disabled riders and wheelchairs seen near Prague's central Florenc bus station in the Czech Republic in April 2010.

it is widely acknowledged that buses employing low-floor technologies could provide a more reliable and cost-effective accessibility answer and are the vehicles most appreciated in the current bus market.

Low-Floor and Kneeling Buses

A low-floor bus is a bus that, between the two doors (usually at the front and in the middle), has a vehicle floor sufficiently low and level enough to eliminate the requirement for steps in the aisle both between these doors and in the vicinity of the doors. In order to put this into context, one has to compare the key design specifications that define a low-floor bus with those of a traditional bus. The floor of a traditional bus is flat and continuous and is approximately 35 inches above the street. Access to the floor level is provided by stairs at both the front and rear doors. The floor height of a low-floor bus is approximately

15 inches off the street between the front and rear doors. The floor area over the rear axle is raised, and access to this area is available either by steps or by a ramp in the floor.

Low-floor buses provide a relatively large area without seating (or seating that folds up) next to one of the doors, where wheelchairs and strollers can be parked. When there is no wheel-oriented externality on board the areas can allow high occupancy for passengers who are standing. Priority seats for seniors and disabled passengers are not designated in the wheelchair location but in close proximity to the low entry door. The position of the wheelchair usually faces the rear of the bus, resting against the bulkhead. Safety requirements are met by this concept since no accident to a wheelchair occupant has been reported on a city bus.

Usually there is a strict restriction allowing only one or two wheelchairs or pushchairs on at the same time in order for them to be accommodated while unfolded. This is for safety reasons. The most common occupied adult wheelchair is usually 43 to 47 inches in length and 24 to 28 inches in width and is about 19 inches longer than an unoccupied wheelchair. According to the International Organization for Standardization (ISO) the smallest turning circle of a wheelchair, including footrest, is, in practice, 6 feet.

Low-floor buses provide user-friendly access through a boarding assistance system either with the use of an extendable ramp that provides nearly level entry or with a kneeling system, usually based on air-suspension. A low-floor bus that is defined by its hydraulic or pneumatic kneeling device is known as a kneeling bus. This feature allows the driver, when the vehicle is not in motion, to actually lower the bus to the curb surface, making entering and exiting a much easier process for everybody, including mobility-challenged passengers. Depending on how close to the curb the bus can be parked, this system can allow wheelchair users to board unaided. The kneeling bus has no steps in its cabin to impede traffic. Passengers who use wheelchairs, as well as any passenger with mobility limitations, can navigate the entrance of a kneeling bus much more easily than a conventional bus. The main disadvantages of a kneeling bus are time-delay problems because the process of boarding takes longer, vehicle durability because the kneeling operation generates wear and tear on the bus's suspension, and excessive fuel

consumption because extra fuel is used for operating the kneeling device.

Sometimes the accessibility of a low-floor bus is enhanced by the bus stop pavement design. Specially raised sections of curb could allow easy access to some low-floor models, although this is an expensive alternative that may only be feasible for very frequent and popular routes and cities committed to inclusive design and modal shift initiatives.

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See Also: Accessibility and Mobility; Bus Capacity; Bus Design; Buses; Handicapped Access; Transit Dependence; Transit Vehicle Capacities, Loading Criteria and.

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Bus Engines

Mass transportation depends on a reliable system utilizing vehicles that can transport individuals and materials to and from destinations. Buses are an important mode of transportation. From a yellow school bus to a bus in a major city, these elite people movers make the world mobile. Like the human body, the propulsion system (engine) needs energy to work. The energy for a bus comes in the form

of fuel. Depending on which type of engine is used by transit agencies, the fuel must be designed specifically for the bus. Currently, buses utilize three different types of fuel: diesel, liquefied natural gas (LNG), and electric.

In the beginning, diesel engines were the cheapest and easiest manufactured in the United States. Diesel engines use diesel fuel to keep the engine running smoothly. Because of technological advances, other sources of fuel for buses have changed the way transportation departments fill up the tanks. These two types of fuel are LNG and electric.

Diesel

For thousands of students who have pulled into the school lot safely in the sea of yellow buses or a group of senior citizens embarking on a trip to the casino in the comfort of a climate-controlled bus, diesel fuel helps make these excursions possible.

Diesel fuel is cost effective and provides roughly 2 to 3 miles per gallon. Also, the cost of a diesel-engine bus is \$300,000 whereas a gas-engine bus costs \$30,000 more. While the cost and fuel efficiency may be attractive to keep buses on the road, the emissions from diesel fuel have created a strain on the environment. Alternatives to diesel fuel have been changing the newer fleets of mass transportation that are hitting the streets, especially in towns that are in a constant chokehold of smog and other pollutants.

LNG

Besides diesel, natural gas has been used as fuel for buses. Since natural gas is flammable, there has been a concern that the gas will cause an explosion. Due to this concern, an alternative to the use of natural gas has been developed. This alternative is liquefied natural gas, referred to as LNG. This type of fuel is extracted as a clear, colorless gas that does not produce any odor or corrosive or toxic substances. The conversion process from natural gas to a liquid is called liquefaction. This process involves taking the methane portion of the gas and cooling the substance to minus 259 degrees F, which takes the gas to below its boiling point. Upon completion of this process, concentrations of hydrocarbons, water, carbon dioxide, oxygen, and sulfur compounds are extracted and removed from the gas, thus decreasing the amount of emissions polluting the environment. Since LNG is in liquid form, it is half

the weight of water, causing LNG to float on top of water if the LNG is exposed to standing water.

LNG comes from major gas reserves in Algeria, Australia, Brunei, Indonesia, Libya, Malaysia, Nigeria, Oman, Qatar, and Trinidad and Tobago, and is transported to import sites in the United States—California, Massachusetts, Maryland, Georgia, Louisiana, and Puerto Rico, a U.S. territory. Within the state of California, there are over 40 LNG terminal locations that are near major roadways. When LNG is received at the terminals, it is placed in insulated containers that are specially designed to keep the LNG cool so it will not evaporate. A terminal LNG site can cost over \$1 million. LNG is used for vehicles that have a Class 8 (33,000–80,000 pounds weight) rating.

Transport systems that are looking for an alternative way of fueling buses will benefit from the use of LNG because it is easy to transport and costs less than diesel fuel or natural gas. Also, LNG produces low emissions and NO_x in comparison to the high emission rate of diesel fuel.

Electric

As diesel fuel and LNG are key components in keeping buses at the top of the world's transportation system, another means to keep buses humming on the roadways is use of electrical power. Electrical power fuels buses by the use of rechargeable electric batteries. One transportation system using electric batteries is in California along the Foothill Transit Route 280 through Azusa. Once the charge is depleted, the buses are recharged in stations during a scheduled off-duty time. A drawback to the electric battery system is that the bus routes are shorter because the buses have to get several charges throughout the day; a charge is only good for 200 to 300 miles.

Operating like the electric battery system, another fuel alternative has been created by the use of hydrogen. Hydrogen fuel cells are cheap and do not produce any pollutants except heat and water output. Unfortunately, technological problems as well as the lack of available hydrogen charging stations will likely keep this alternative from being a popular fuel choice for buses.

Diesel-Electric Combination

In addition to the standard propulsion systems for buses, a new propulsion system has been created for a hybrid bus that runs on a combination of

diesel and electric. Just like a hybrid car or truck, the hybrid bus starts with the diesel engine and changes to an electric engine when the vehicle begins to reduce down to a coasting speed.

Cheaper than a diesel-engine bus, the cost for a hybrid-powered bus can range from \$100,000 to \$200,000. Diesel-electric fueled buses are better on fuel than diesel- or gas-powered buses. However, the diesel-electric buses create more pollutants than regular electric-powered buses. Due to being efficient in cost and fuel economy, hybrid buses have been an excellent choice for transportation departments.

As environmental concerns and the increase in fuel prices affect how mass transportation can meet the demands of an ever-changing world, transportation departments must be diligent in determining which type of fuel will be used in their buses.

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See Also: Alternative Fuels; Bus Design; Bus Rapid Transit; Buses; Diesel Engines; Diesel Fuel Vehicles; Electric Vehicles; Vehicle Fleet Emissions.

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Bus Information Systems

One way to increase ridership on public transit systems is to improve the quality of the user experience. Because many passenger complaints center

on the uncertainty of using public transit, particularly bus systems that operate on the same roads as automobiles and thus are particularly subject to traffic delays, providing accurate information about the arrival of the next bus at a particular stop goes a long way to removing that objection, even if it cannot remove the uncertainty itself. Bus information systems have been implemented in many cities around the world and have been shown generally to improve rider satisfaction and sometimes to also be associated with an increase in ridership.

Psychology and Technology

Many people find waiting with uncertainty particularly tedious, and studies have found that the lengths of waits are often overestimated when a person does not know how long a wait will last. In the case of bus systems, an additional factor of perceived safety may intensify this experience, as people may be reluctant to use the bus system at night if they are uncertain how long they may have to wait in a dark area that they perceive as potentially dangerous. Providing accurate information about the expected length of a wait, whether by a range of minutes or by a countdown format, has been shown to reduce this overestimation of wait time. In addition, this information allows people to judge when they need to be at the bus stop, and thus when they need to leave their house, whether they have time to run an errand before getting on the bus, etc.

The roots of today's real-time bus information systems lie in technology developed in the 1980s and 1990s to allow transit systems to track the location of their vehicles. Known as automatic vehicle location (AVL) systems, this technology was first used to help transit systems increase their operating efficiency and only later was adapted to provide information to customers.

European municipalities were the first to use AVL systems to provide customers with real-time bus arrival information. The first INFOPOLIS survey, conducted from 1996 to 1997, described over 50 European transit systems supplying real-time information to passengers; the second INFOPOLIS survey, conducted in 1998–2000, described over 150 such systems operating in Europe. By way of contrast, as of 2000 in the United States, just 88 transit systems were using AVL data to supply real-time information to their passengers, although

another 142 systems were in the process of developing such programs.

Most real-time bus information systems use GPS (global positioning system) AVL systems to locate vehicles, while some use signpost and transponder systems or other methods. In any case, vehicle location information is combined with operations data (e.g., the travel time between two bus stops, based on the last several trips on a particular route), information about current and past traffic conditions, etc., to estimate vehicle arrival time at a particular stop. Some systems provide additional information, such as the time to the next few stops. Algorithms are used to make this estimation, and different transit systems use different models, based on their needs and the characteristics of their operating environment. In addition to providing arrival information, most transit systems regularly monitor the accuracy of the information provided, so adjustments can be made to the algorithms necessary; unfortunately, such monitoring often drops off the longer a system is in service, thus potentially reducing the benefit of the program by providing inaccurate information to customers.

To communicate arrival information to passengers, early systems used signs at bus stops, usually incorporated LED (light-emitting diode) or liquid crystal displays to show current information about the expected arrival of the next bus. More recently, this information is also being made available on the Internet and on mobile devices (e.g., mobile phones); only the latter are used in many recent systems, thus avoiding the costs of constructing and maintaining electronic signs but with the disadvantage of not making arrival information accessible to people who do not own the type of device required. In general, bus information systems improve customer satisfaction, and users often perceive that the transit system has improved, and some systems have also seen increased ridership.

Case Studies

Kari Watkins and colleagues studied the OneBusAway traveler information system in King County, Washington, in 2010, focusing on the area in Seattle around the University of Washington. They found that providing arrival information lowered real waiting time for passengers by 31 percent (meaning their actual wait was shorter, because they could

more accurately plan their arrival at the bus stop) and also lowered perceived waiting time. In addition, better information about bus arrival time was seen as being more important to users than service frequency and also compensated somewhat for buses going off schedule (meaning passengers were less concerned about a bus being late than the fact that they did not know it would be late).

Whereas those without arrival information tended to overestimate the time they spent waiting by almost a full minute, those provided with the arrival information estimated their wait time much closer to its actual length. Those using the OneBusAway program also expressed higher satisfaction with the public transit system and used the transit system more frequently. The OneBusAway system required passengers to access information through mobile phones, and the authors suggested that although the OneBusAway program was successful in its goals, that same information needed to be provided through other means for those who did not own a mobile phone.

Lei Tang and colleagues, studying the Chicago Transit Authority (CTA) system from 2002 to 2010, conclude that the CTA Bus Tracker, an on-time information system, was responsible for a modest but significant increase in ridership, after controlling for many other factors including gas prices, unemployment, and weather conditions. They also found that the increase was greatest on the bus lines where the CTA Bus Tracker system was implemented later (over the entire system, implementation took place between 2006 and 2009) and suggest that this may be due to diffusion of information, whereby potential riders were more aware of the system later in its implementation.

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See Also: Bus Routes; Bus Scheduling; Bus Stops/Shelters; Commuter Buses; Transit Information Systems; Transit Performance Monitoring and Evaluation; Transit System Technology; Transit Systems, Service Quality of.

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Bus Priority Lanes, Exclusive Right of Way

Buses operating in priority lanes that are located within an exclusive right-of-way (often referred to as bus rapid transit, or BRT) represent the highest order priority treatment for non-fixed route transit. These lanes are permanent physical elements within a transport network, often collocated with a general traffic corridor, that permit buses to avoid congestion, maintain a consistent and reasonable operating speed and keep to a timetable (that is, operate reliably).

Bus priority lanes within an exclusive right-of-way avoid interaction with traffic entirely, rendering the highest operating benefits. General traffic is typically excluded through physical barriers separating the priority lanes from adjacent traffic lanes, and entry to the priority lanes may be controlled through transit-actuated gates and/or "sump busters." This style of bus priority can be a precursor to development of light rail transit (LRT).

BRT is most effective as a line-haul transit solution, more akin to heavy rail where there is typically

significant separation between stops. This is in contrast to traditional bus services where routes tend to weave through local communities and there are frequent stops.

Urban Transport Systems

Urban environments are increasingly under pressure for transport infrastructure to be used to its fullest potential. Historically, this has been in the form of increasing lane utilization such as through the introduction of clearways at peak times or contraflow lanes. While these measures are effective in increasing corridor capacity, they do not specifically benefit transit services and do not encourage a shift from private vehicle to transit, which is on the agenda in many cities.

The introduction of BRT can increase significantly the capacity of a transport corridor where there may be limited opportunities for road widening and adding additional road space. This is because buses can carry far more passengers than private vehicles per operating traffic lane, all things being equal.

Recent peak hour surveys undertaken on a busy inner-city corridor connecting the central business district and a major university in metropolitan Perth, Australia, identified an average occupancy of 1.2 persons per private vehicle. The average bus occupancy in the peak hour along the same corridor was approximately 40 persons per vehicle.

In urban environments, a lane of traffic has a saturation flow of up to about 1,900 vehicles per hour. Applying average vehicle occupancy of 1.2 persons per vehicle, the theoretical capacity of the lane would be 2,280 people (assuming that the lane is solely used by private vehicles). In comparison, a bus service operating at a frequency of one vehicle per minute with an average occupancy of 40 persons per vehicle could move the same number of people.

The warrant applied by the Public Transport Authority of Western Australia is for a minimum of 10,000 passengers per day to utilize a BRT corridor for the investment to be justified. On busy corridors in some cities, this minimum threshold can be surpassed considerably. Caracas, the largest BRT corridor in Bogotá, Colombia, carries up to 45,000 passengers per day (two-way).

The most significant benefit of the exclusive lanes is that they provide the greatest degree of certainty of travel time for patrons. This is because rolling stock does not mix with and get delayed by

other modes of transport. This is key differentiator of BRT from semi- or nonexclusive bus lanes along a corridor where vehicles can legitimately enter a bus lane when making a movement to/from a side street or driveway.

Exclusivity, the defining feature of BRT, can provide a high degree of route legibility for users. However, it can also present challenges in terms of implementation. In order to achieve physical separation, significant investment often needs to be made—particularly if the system is grade separated—and the effects on the connectivity of the transport network for other modes of transport can be severely curtailed. Accordingly, BRT may be an appropriate treatment along major transport corridors but is less likely to suit a highly urbanized context where place activation and network permeability are important.

Segregating BRT From General Traffic

BRT systems either have continuous segregation from general traffic at-grade or are grade-separated from general traffic. At-grade continuous separation can be in the form of curbing or barriers. Cross movements by general traffic have to be facilitated through installation of under- or overpasses. Given the costs associated with these crossing treatments, they are typically spaced some distance apart (e.g., 2 to 3 miles minimum) at arterials rather than lower-order roads.

Grade-separated systems may be in tunnels, cut, or elevated, or a combination of the three. Accordingly, no further physical treatments tend to be needed to prevent general traffic from intruding into the lanes. However, gates are required to limit entry to the system. Often, such entry systems are triggered by a GPS transponder on board buses when they are on approach.

Dimensions of Exclusive Rights-of-Way

The width of the right-of-way varies depending on the dimensions of rolling stock, the number of operating lanes required, and the type of physical separation that is employed to prevent intrusion by general traffic. In locations where there are high tidal flows, lanes can be allocated dynamically in peaks, reducing the overall lane requirements.

Where lanes are adjacent to high walls or barriers, a minimum buffer of 1.5 feet (0.5 meters) should be provided, measured from the vehicle's mirrors.

This is to create a safety margin to assist drivers and becomes more important at higher operating speeds. A typical lane width is 12 feet (3.5 meters), which is the standard used by authorities, including Western Australia's Public Transport Authority.

A minimum vertical clearance is required through tunneled sections and along routes where there are overpasses and other overhead obstructions. Again, the minimum standard depends on the rolling stock that is used, but a 15- to 16-foot (4.7–5-meter) clearance is typical. Such a clearance can also permit use of the BRT system by other vehicles when necessary (for example, emergency services vehicles) and facilitate conversion of BRT to light rail, if desirable in the future.

Numerous other minimum and maximum design requirements apply to BRT systems, covering variables such as cross-falls and super-elevations, inter alia. The American Public Transportation Association (2010) has published guiding material in this regard.



King George Square Station in Brisbane, Australia, is sunk beneath land development. Use of either elevation or tunneling may allow integration with development and reduce at-grade general traffic congestion and interchanges.

Land Use Requirements and Cost

Land use requirements depend on whether BRT is constructed at-grade or is grade-separated. Exclusive bus lanes constructed at-grade tend to have the most significant land use requirements. Devices to separate the bus lanes from general traffic lanes and prevent intrusion by unauthorized vehicles add to the width of the corridor. Furthermore, in locations where road crossings are required, structures are needed to grade separate the roadway and bus lanes. Aside from the costs associated with these structures, additional land may be required if ramps are needed to permit buses to access the wider road network.

Where exclusive bus priority lanes are elevated, land requirements can be minimized whether the bus system sits on a deck above land use or the road used by general traffic. Elevation can permit BRT to take direct routes rather than follow defined infrastructure corridors.

Elevated systems are expensive relative to at-grade solutions given the structures required. Moreover, such systems generate noise and light spill and visual impacts. On these bases, the travel time benefits associated with elevation need to be weighed against negative impacts on amenity and capital costs. Tunnels offer similar flexibility to elevated systems without the same visual, noise, and light spill impacts. However, they are considerably more expensive again to deliver, all things being equal.

The Brisbane Bus Rapid Transit system in Australia has sections at-grade, elevated, and in tunnels. The primary reasons for elevation and tunneling (in selected locations) are to avoid at-grade general traffic congestion and interchanges, integrate with development, and permit more direct linkages between urban centers.

Implications

BRT is intended to move large numbers of people efficiently. This makes it an attractive system within a congested urban environment. Nevertheless, providing a high degree of exclusivity for bus services at-grade—being the cheapest way to deliver BRT—requires that access to the corridor by other modes is reduced. This can create a less permeable network. General traffic can be concentrated on fewer routes, adding to congestion issues and impacts on amenity for properties along these routes. Critically, the loss of permeability and added congestion can

affect local feeder bus services, necessitating added priority treatments such as queue jump lanes.

The reallocation of road space from general traffic and added congestion that can result from reductions in permeability may be part of a deliberate planning agenda. If trips by private motor vehicles (especially in peak hours) are made less attractive, greater use of the BRT system can be leveraged.

In practice, impacts on local traffic and accessibility require detailed investigation and need to be contrasted with the benefits associated with BRT. This analysis should include macro-scale modeling to understand changes in key metrics, such as trip lengths (measured by vehicle kilometers/miles traveled) or travel time (measured by vehicle hours traveled). A scheme that leads to higher travel metrics could be counterproductive if an intention of the BRT project is to improve local air quality.

The impacts of BRT on accessibility for pedestrians and cyclists also require close scrutiny. For example, pedestrian crossings need to be clearly signposted, and located along key intersections and may require grade separation or barrier/gate control (if located at-grade). On busier systems, at-grade pedestrian crossings should not be constructed because of safety reasons.

Stops and Stations

BRT stops and stations tend to take on characteristics of LRT or metro rail rather than suburban bus stop facilities. This reflects the high patronage of the system and the need for a quality boarding and alighting experience. Per the Brisbane example, busier stations in urban centers, particularly where they are integrated with land use, can be sunk or elevated so boardings and alightings are as seamless as possible.

Otherwise, careful attention needs to be paid to how pedestrians and cyclists access the BRT system. Furthermore, feeder bus services may need to interchange with BRT in certain locations. The TransMilenio system in Bogotá, Colombia, features bus lanes located in the median of a transport corridor with adjacent general-traffic lanes. Pedestrians have to access the station via overpass facilities.

Bypass/overtaking facilities can be required at stations, depending on the capacity of the BRT system (for example, how many lanes are provided in each direction) and the frequency of services that use it. The purpose of bypass/overtaking facilities is

to avoid delays to express services associated with waiting for stopped shorter-haul services at stations.

Finally, the ability to load and unload passengers quickly is an important factor to achieve the greatest benefits with a BRT system. Critical variables in this regard include use of low-floor vehicles, automated ticketing systems, sufficient platform capacity, multiple doors on vehicles, and real-time information availability.

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See Also: Bus Design; Bus Rapid Transit; Bus Systems, Local and Express; Busways and Reversible Bus Lanes; Light Rail Transit; Transit Priority Measures.

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Bus Rapid Transit, Design and Engineering of

Bus rapid transit (BRT) is a recently developed low-cost bus-based alternative to metro and tram

systems. A BRT system emulates the performance and amenities of modern rail-based transit systems, including segregated rights of way, closed stations, and pre-board ticketing. However, it has major advantages over rail-based transit, including much lower construction costs, short implementation periods (one to three years after conception), accommodation of many route permutations, and flexibility to adapt to a range of urban conditions.

In the last few decades, BRT has become widely used for urban mass transit, especially in developing cities. More than 40 cities on six continents have implemented BRT systems, and at least as many systems are either in the planning or construction stages. The Institute for Transportation and Development Policy, an international nonprofit organization headquartered in New York, and EMBARQ, a program of the World Resources Institute, a global environmental think tank in Washington, D.C., have been instrumental in promoting BRT systems around the world.

History

The term *bus rapid transit* (BRT) emerged in North America and Europe. Around the world, the concept has been described by different names, including Metro-Bus, surface metro, express bus systems, busway systems, high-capacity bus systems, and high-quality bus systems. The origins of the BRT concept date back to 1937 when the city of Chicago outlined plans for three inner-city rail lines to be converted to express bus corridors. In the first few postwar decades, exclusive busway plans were prepared for several cities in the United States, including Washington, D.C., (1955–59), St. Louis (1959), New York City (1963), and Milwaukee (1970). In Europe, the first exclusive bus lanes were implemented in Paris in 1964. The first dedicated median busways appeared in Belgium (in Liege) in 1966. The first developing-city busway was built in Lima (Peru) in 1972. The creation of the first “bus-only” street was also in 1972 in London, with the closure of a city center corridor to private car traffic.

However, the development of busways did not gain momentum until the early 1970s, when the first oil crisis pressured governments to improve public transport and customers to reduce car use. Curitiba's (Brazil) system opened in 1974, marking the modern era of BRT development and contributing to the city's global reputation as an urban success story.

With the abatement of the first oil crisis, interest in public transport diminished. While the 1980s did experience the advent of the first “guided busways,” mainly in western Europe, the concept saw relatively little further adoption due to the comparatively high infrastructure cost.

In the late 1990s, the explosion of private motorization and congestion and declines in public transport ridership in developing cities, combined with the low quality of transport services provided by informal-sector minibuses, motivated the search for quick and cost-effective public transport solutions. BRT’s profile became more widely known, especially in Latin America and Asia but also in the developed world.

In 1996, Quito (Ecuador) opened a BRT system using electric trolleybus technology. In 1999, Kunming developed the first median busway system in China. Taipei (Taiwan) also developed a median busway system, with the first corridor put into place in 2001. In 2010, the largest BRT system in Asia was implemented in Guangzhou (273 kilometers, 800,000 passengers/day). In developed nations, new BRT systems were put in place in Vancouver (Canada) in 1996, Miami (United States) in 1997, and Brisbane (Australia) in 2000. In France, technological innovations produced highly sophisticated vehicles (that is, with rounded body, covered wheels, and optical guidance systems), which minimized the distinction between BRT and light rail.

However, BRT was not yet viewed as a serious mass transit option capable of rail-like service. It was widely believed then that BRT could serve only a niche market of small and medium-sized cities or a few isolated corridors in large cities. At a reasonable speed, BRT’s maximum capacity was estimated to be only 12,000 passengers/direction/hour/lane.

The arrival of the “TransMilenio” BRT system in Bogotá (Colombia) in 2000 radically transformed the perception of BRT around the world. As a large and relatively dense city (7 million inhabitants, 240 inhabitants/hectare), Bogotá demonstrated that BRT is suitable for megacities. As of 2011, the TransMilenio system encompassed 116 kilometers of trunk corridors and 446 kilometers of feeder routes, moving more than 2.5 million passengers per day.

Key Characteristics

Typically, a BRT system has the following characteristics: (1) segregated busways or bus-only roadways



A bus rapid transit (BRT) Metrobús in Mexico City, Mexico, in 2010. The bus is separated from other traffic by a series of concrete curbs in the street. The success of Bogotá, Colombia’s BRT system led to more use of BRT in megacities like Mexico City.

over the majority of the system’s trunk/city center corridors; (2) location of the busways in the median of the roadway rather than in the curb lane; (3) an integrated “network” of routes and corridors; (4) convenient, comfortable, secure, and weather-protected stations; (5) articulated vehicles with level access between the platform and vehicle floor at stations; (6) nodal stations and terminals to facilitate physical integration between trunk routes, feeder services, and other mass transit systems (if applicable); (7) pre-board fare collection and fare verification; (8) fare integration between routes, corridors, and feeder services; (9) entry to system restricted to prescribed operators; and (10) distinctive marketing identity for the system. Other essential characteristics of a successful BRT system are qualitative in nature and include its impacts on the citizenry, that is, a sense of community pride and confidence.

Local circumstances (that is, city size, population density, trip distribution, climate, geography,

topography, financial resources, technical capacity and knowledge, existing business and institutional structures, culture, and political will) dictate the extent to which the above characteristics are necessary or feasible to achieve within cost constraints. The Institute for Transportation and Development Policy has instituted the BRT standard, a scoring system and planning tool, which certifies a BRT corridor as basic BRT, bronze, silver, or gold, thus placing it within the hierarchy of international best practice. In smaller cities, a basic BRT system might be sufficient to meet most residents' travel needs.

Most BRT plans are a combination of rational analysis and advocacy for a certain set of solutions and interventions. They generally cost in the range of \$1 million to \$3 million, depending on the complexity and size of the city as well as the consultant fees, and can be completed within a period of 12 to 18 months.

The most successful BRT systems to date have been initiated and led by charismatic political leaders, such as the former mayors Jaime Lerner of Curitiba (Brazil) and Enrique Peñalosa of Bogotá (Colombia). Some cities have intentionally created new agencies or public companies, which bypass the established regulatory agencies, to oversee the development of a BRT project.

BRT corridors are selected based on multiple factors, including customer demand, network advantages, roadway characteristics, ease of implementation, costs, political considerations, and social equity. The likely demand for a new BRT system is approximately equal to the existing public transport ridership along proposed corridors plus a percentage of new passengers (that is, a 10 percent shift from private vehicles, depending on local circumstances). However, computer modeling (such as the EMBARQ BRT Simulator) is required for more precise estimates.

A major BRT operational distinction is between a "trunk-feeder" configuration and a "direct services" configuration. A trunk-feeder system allows smaller vehicles (feeders) to be utilized in lower density areas while the main corridors (trunks) operate with larger vehicles. Although this configuration is more efficient, it also requires more terminal transfers. By contrast, direct services use a single vehicle to connect destinations (that is, a residential area to the city center). Direct services help reduce the number of transfers required but

they are more costly. To date, most direct services have been utilized within lower quality open systems (see below).

A standard BRT lane is approximately 12 feet (3.5 meters [m]) wide, while stations are generally 8 to 16 feet (2.5–5 m) wide. A standard busway with a single lane in each direction requires 32 to 42 feet (10–13 m) of road width. A BRT system that comprises express services (with passing lanes at stations) requires up to 65 feet (20 m) of road width. Solutions to overcome roadway limitations in historical centers and business districts include use of median space, expansion of roadway width, transit-only streets ("transit malls"), fixed guideways (bus tracks), grade separation, and operation in mixed-traffic lanes.

System speed and capacity depend on many factors, including multiple stopping bays at stations, express and limited-stop services, articulated vehicles with multiple wide doorways, off-board fare collection and fare verification, platform level boarding, and optimal station spacing. To date, the highest capacity BRT system (Bogotá's TransMilenio) serves more than 45,000 passengers/hour/direction. A standard BRT system without passing lanes for express services serves a maximum of 13,000 passengers/hour/direction. Most high-quality BRT systems achieve average speeds of 15 to 20 mph (23 to 30 km/h).

In general, a BRT system costs between \$1 million and \$8 million per kilometer to construct, depending on factors such as the complexity of the street environment, the need for flyovers or underpasses, the number of busway lanes, and the need for property acquisition. This amount is 5 to 20 percent of the cost of a tram or light rail transit system and 1 to 10 percent of the cost of a metro system. International development banks, especially the World Bank, are increasingly interested in supporting BRT projects.

The business structure of a BRT system is primarily defined by the system type: a "closed system" or an "open system." A closed system implies that the corridor access is limited to an approved set of operators and a restricted number of vehicles. By contrast, an open system permits any existing operator to utilize the busway. Experience to date has shown that open systems have lower quality than closed systems and are prone to busway congestion, particularly at stations and intersections. A privately operated, competitively tendered BRT

system, in conjunction with a strong oversight role by a public agency, generally provides the optimal incentives for profit and customer service.

BRT vehicle technology options involve both the vehicle size and the propulsion system. For high-demand corridors, 160-passenger articulated vehicles are standard. Feeder vehicles from lower density areas typically range from small minibuses or vans to standard-sized buses, depending on area demand.

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See Also: Bus Capacity; Bus Rapid Transit, Design and Engineering; Bus Scheduling; Bus Systems, Local and Express; Busways and Reversible Bus Lanes; Transit Systems.

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to fill social needs; those that exist for social needs may be unprofitable but serve some greater social benefit. Ultimately, the structure of the system, and the objectives of officials overseeing that system, will dictate what is deemed important. Regardless of the motivations of officials, foresight is a critical aspect of managing bus routes.

There are three major types of bus systems: hub-and-spoke systems, in which all routes radiate from a central point; grid systems that grant access to passengers through strategically placed lines; and flexible systems that serve as a hybrid of traditional bus systems and taxi services. No matter which system they adopt, administrators must remember that what works today may not work tomorrow. This may seem like common sense or mere proverbial wisdom, but it is backed up by top economists. City planners must be ever aware of trends and social forces within their cities so that they may prepare the bus routes of tomorrow, even if they never use them. If they do not, they risk their mass transit system becoming ineffective, along with the social and economic damage that may ensue.

The planning of bus routes is by no means a task that can be completed once, then forgotten. Planning is a dynamic process that is in constant need of revision. Studies by economists employed by the World Bank Group have consistently shown that route planning always lags changes in demand. Thus, in order to maintain operating transportation systems, administrators must be constantly revising their current systems. What works and what does not is not always clear in planning bus routes; often it is merely a matter of trial and error. There are those who contend that market forces should be the sole consideration in determining bus routes. However, while most experts agree that market forces should be taken into consideration, it is widely agreed that social forces outside profit motives should play a role when determining bus routes.

Elements to take into consideration when planning routes often include surveys, vehicle operator input, economic forecasts, traffic demand forecasts, and other relevant trends predicted within the region. It is true that some metropolitan transit systems work for decades without need of revision. However, planners should be aware that society is dynamic, and unforeseen changes could always make swift adaptation necessary.

Bus Routes

Effective bus routes are critical to the overall efficiency of any mass transit system. If certain lines are overcrowded, others can become underused and valuable resources, as well as passenger time, may be wasted. Bus routes may be laid out based on profit motives. Other routes may be put in place

Types of Systems

There are three types of planning systems that may be used in determining bus routes. The first, and most historically prevalent, are hub-and-spoke systems. In this old system that relied on one central bus station, all routes came together at a central point or station. Passengers were able to get between any two points by traveling to the central station then transferring to a second bus that would take them to their final destination. When this type of system is effective, it works because most trips are short and service buses arrive at stops frequently, thus minimizing transfer times. When this type of system does not work, it is often because regular commuter traffic and congestion are a problem and a high proportion of indirect routes create a quagmire of prolonged inefficient journeys. This second scenario is more typical in the hub-and-spoke system, which may be why they are increasingly being replaced.

Grid systems consist of a series of route networks in which routes are arranged in either a grid of interconnected lines or concentric circles with connector lines. Compared to hub-and-spoke systems, grid systems have been described as more direct because a passenger may “ride like you drive.” Thus, a passenger may travel from one part of a system to another without having to travel through a central bus station, as with the traditional hub-and-spoke model.

Flexible route systems may exist on their own or be integrated into hub-and-spoke or grid systems. Routes are planned on a short-term basis and are arranged within hours based on individual requests; for this reason, these systems are also known as “demand-responsive systems.” Flexible route systems are highly individualized and transport passengers from their origin to their destination, in contrast to hub-and-spoke or grid systems that operate on the premise that passengers must travel according to existing lines.

Whether they exist independently or are integrated into other types of systems, flexible route systems improve efficiency in areas with sparse demand. When considering efficiency, replacing large vehicles with smaller ones may prove counterintuitive. However, they provide a good alternative to running a full-sized bus to an area. As part of the flexible route system, shuttles operate much like a taxi combined with a traditional bus wherein

passengers are required to share the vehicle with others and be mindful of intermediate stops based on all customers’ needs. In this way, shuttles can facilitate transporting up to 10 passengers per hour.

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See Also: Bus Capacity; Bus Scheduling; Bus Stops/Shelters; Bus Systems, Interurban; Bus Systems, Local and Express; Bus Systems, Rural; Busways and Reversible Bus Lanes; Transit Industry, Economics of.

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Bus Scheduling

The scheduling of regular bus routes involves a number of issues in order to serve passengers efficiently and effectively, with a goal of preventing both overcrowding at one extreme and frequent empty trips at the other. As a process, scheduling follows the placement of a route and the bus stops along that route. (Some such stops may also be used for other routes, when routes intersect.) The intersection of the route with other routes may impact the scheduling process—for instance, it may be desirable to schedule buses to arrive at a

given stop a certain amount of time before another bus (or other form of transit) departs from that stop if passengers are expected to frequently transfer from one to the other. The terminus locations may also impact the scheduling, when the route is expected to be used by commuters, in which case trips need to be arranged around work hours and will probably be less frequent later at night. Conversely, routes that connect residential areas to downtown areas need to operate sufficient trips in the after-work hours in order to serve downtown businesses and in some areas may be best advised to operate late-night trips to accommodate the time when entertainment venues, restaurants, and bars close for the night.

Scheduling is also impacted by the changing conditions throughout the day that affect how long it can take a bus to traverse the route. When possible, planners avoid streets with school zones, traffic circles, speed bumps, and other traffic-slowing measures, as well—at the opposite extreme—as major arteries and high-speed streets, where bus stop placement is problematic. Total avoidance of these circumstances is not always possible or practical, and variable traffic patterns throughout the day (the dense traffic of the commute hours, the moderate traffic of the workday, the lighter traffic of after-dinner hours, as well as the impact of school zones, school bus traffic, and other temporal factors) can have a serious effect on the length of time a route may take. Extra routes may need to be added in bad weather, such as in the winter, when the general speed of traffic has been slowed enough that the difference between scheduled arrival times and actual arrival times quickly expands and distorts the schedule.

Scheduling is also affected by dwell time, the time the bus spends in any given place, whether a terminus or a bus stop. Different methods of fare collection impact dwell time, as passengers searching for exact change that must be counted by the driver take longer than passengers who feed exact change into a machine, who in turn take longer than passengers using a machine that can give change back from overpayment, who in turn take longer than passengers using cards or passes that are read electronically. For buses without on-board fare collection—such as school buses, free buses, or ticketed buses whose passengers have already paid at the ticket counter—dwell time is affected primarily by the number of passengers

embarking or disembarking at any given stop. Crowded buses can experience greater dwell times as it is more difficult for passengers to find a seat or to board. Dwell time may also be affected by passenger age and similar factors. Schoolchildren can be expected to take longer to board than adults, and routes serving retirement homes will be used by elderly passengers who are slower to move and who should be assured of finding a seat before the bus resumes motion.

Scheduling must also take headways into account. Headway is the distance (or time) between buses on the same route. On a route served by a single bus, the headway is the amount of time it takes to travel the route, plus any scheduled dwell time at a terminus. But many routes with greater ridership are served by multiple buses whose schedules are staggered, such that a bus arrives at a given stop every 15 minutes, for example. The headway of a route affects the route capacity, that is, the number of passengers who can be served by that route each day. Headway also impacts passenger wait time, which in turn can impact dwell time, and thus route time: if passengers are picked up frequently enough to reduce the number waiting at any given time, then the contribution of passenger boarding to dwell time is reduced in proportion to the reduction in the size of the bus stop crowd.

Scheduling also must account for labor needs. Buses are not autonomous. Route schedules are divided into the run cut—blocks of driver assignments to particular runs, including straight runs (in which the driver drives the route continuously for a given block of time, usually eight hours), split runs (two short straight runs separated by an unpaid break period), and trippers (short blocks of less than three hours, typically a single run of a route, such as driven by school bus drivers). Modern bus companies use software to construct schedules, but the user still needs a level of expertise in order to know how to use the software, how to establish the rules by which it will be governed, and what the needs are of the bus company and its passengers.

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See Also: Bus Routes; Bus Stops/Shelters; Bus Systems, Interurban; Bus Systems, Local and Express; Bus Systems, Rural; Buses.

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Bus Stops/Shelters

Bus stops, the most common type of transit stop, are an essential yet often overlooked element of safe, timely, and convenient transit service. Since bus stops are the first point of contact between passengers and the bus service, the quality of the stop environment can be as important to passengers as the quality of the in-vehicle experience. Bus stops also control the number of stops buses must make and ensure that passenger loading occurs in safe, appropriate places. Therefore, bus stop characteristics can have a significant impact on customer satisfaction, safety, traffic flow, pedestrian movement, and overall transit system performance. Although bus stops are a common fixture in the urban landscape, they vary greatly in terms of operational features, scale, placement, spacing, design elements, and passenger amenities. Despite their diversity, all bus stops should offer a suitable location, safe pedestrian access, visibility for vehicles and waiting passengers, and access for people with disabilities.

Bus stops are typically placed on the sidewalk next to the street and use the edge of the roadway for passenger loading, as distinct from off-line facilities such as transit centers, which are removed from the path of the roadway and use designated areas for passenger loading. Bus stop infrastructure ranges from simple pole and sign arrangements to basic shelters to sophisticated structures. In general, the scale of a bus stop reflects the level of passenger activity. The most rudimentary stops have no identifying infrastructure and may be known only by their description.

However, most fixed-route bus services use designated stop locations, marked with a simple pole and sign, at a minimum. Depending on passenger volumes, busier stops may include additional features such as seating, lighting, shelters, or passenger information signs. Several bus stops may be clustered together to facilitate transfer between bus routes and other public transit modes.

The highest volume stops, such as those used for bus rapid transit (BRT), may be more elaborate and have more extensive passenger infrastructure than a typical bus stop. These stops, often referred to as "stations," usually have seating and a canopy covering a portion of the platform and typically are spaced farther apart than conventional bus stops. To facilitate rapid boarding, they may be constructed with off-board fare collection areas and raised platforms for level boarding. These stations may also include amenities such as lighting, bicycle storage, ticket machines, vending kiosks, emergency telephones, security cameras, artwork, and electronic information displays.

Location

A variety of factors should be considered when determining the proper location of a bus stop, including customer safety, pedestrian access, traffic conditions, parking requirements, other transit stops and connecting services, and surrounding land use. When considering the operations of a route, including any possible constraints such as topography, operators will decide to locate a stop at either the far or near side of an intersection, or mid-block. Far-side stops refer to those placed immediately beyond a signalized intersection. Near-side stops are located at the intersection, immediately prior to the signal. Mid-block stops are located between intersections, usually in a well-defined area. Each type of bus stop location has advantages and disadvantages and should be evaluated individually to determine the best placement for the stop.

In terms of operational use, far-side stops have been found to be the most beneficial, especially when accompanied by transit signal priority (TSP), a preferential treatment for transit vehicles at traffic signals. Because TSP enables the bus to proceed through the intersection before stopping for passengers, dwell time is reduced, essentially decreasing the total travel time for passengers. Far-side

stops also minimize conflicts with right-hand turns, provide more reliable intersection clearance times, and encourage passengers to cross behind the bus, which is safer than crossing in front of it. Some advantages of near-side stops are that they remove the prospect of double stopping for both signal and passenger activity, while also allowing passengers to board and alight closer to the crosswalk. Mid-block stops minimize conflicts with intersection traffic and are most often employed when a major trip attractor is located between intersections.

The distance between bus stops has a strong impact on transit vehicle and system performance, as well as overall travel time and, by extension, demand for transit. As a general rule, bus stop spacing involves a trade-off between the convenient passenger access of closely spaced stops and the improved operating efficiency and cost-effectiveness that are characteristic

of less frequent stops. Bus stop spacing is determined primarily by the urban development context and typically ranges from 600 to 750 feet in central business districts (CBD) and urban areas between 1,000 and 1,250 feet in suburban and rural areas.

Security

In addition to allowing efficient and cost-effective transit operations, a high-quality bus stop should meet the needs of all transit passengers comfortably and safely. Passenger security at a bus stop can have a strong influence on the comfort level of patrons using that stop. Landscaping, walls, advertising panels, and solid structures can restrict sight lines and provide opportunity for concealment. To enhance security, bus stops should be constructed of materials that provide clear, unobstructed views so that waiting patrons can “see and be seen,” placed



An elaborate bus shelter with a glass canopy, stone benches, and extensive maps and signage at Boston's Kenmore station in 2013. Bus stop spacing is determined primarily by the urban development context. Spacing usually ranges from 600 to 750 feet in central business districts and urban areas to 1,000 to 1,250 feet in suburban and rural areas.

at highly visible locations that allow bus drivers to see the stop clearly and permit indirect surveillance from passing traffic and nearby businesses, landscaped with low-growing shrubbery and shade trees that preserve sight lines, and equipped with lighting to improve visibility. Perceptions of security can also be improved with regular maintenance, such as the removal of trash and graffiti.

Accessibility

Accessibility for transit patrons is another consideration agencies must evaluate. Since the implementation of the Americans with Disabilities Act of 1990 (ADA), it has been required that transit service be accessible to all individuals, regardless of disability. If a person with a disability is unable to complete a trip because circumstances make it impossible to do so (for example, uneven ground at a bus stop for a wheelchair user), the individual may access paratransit, a complementary service of public transportation in the United States. Although a beneficial service, paratransit is often very expensive per trip compared to fixed-route services. Because of this and the interest in providing accessible and convenient transportation for all individuals in a community, many efforts are made to ensure that bus stops are accessible to all people, including those with disabilities.

Universal design (also called accessible design or inclusive design) refers to bus stop designs that accommodate the widest range of potential users. Universal design standards address not only people with disabilities but also older passengers; people who are unusually short or tall; people using hand-carts, scooters, and bicycles; and passengers who may be temporarily encumbered, such as a parent with a stroller or someone carrying packages. All new or relocated bus stops must comply with ADA regulations, which include provisions for obstacle-free pathways; stable, slip-resistant surfaces; wheelchair landing pads; minimum horizontal clearances; maximum slopes; and signs that are designed for use by riders with vision impairments. However, efforts should be made to design stations that are convenient to passengers with disabilities, rather than merely meet ADA requirements.

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See Also: Americans with Disabilities Act of 1990; Bus Capacity; Bus Rapid Transit; Buses; Pedestrian-Friendly Design; Transit Centers; Transit-Oriented Development.

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Bus Systems, Interurban

Deceptively old-school by reputation, the bus is a mode of surface transportation that has seen repeated hills and valleys of consumer acceptance and rejection. The bus has often been utilized as a necessity; its business model in the commuting and interurban sense has frequently experienced revival during times of economic downturn, alternating with contraction during periods of general economic growth. On the horizon, however, an era of interurban bus systems expanding and improving in parallel with—and even as a driver of—economic rebound seems to be upon us.

Advantages of the Mode

Interurban bus systems in the United States have in recent decades passed through a time of consolidation and even near-monopoly in various metropolitan corridors and rural regions. More recently, however, a range of influences are providing the impetus for more imaginative and responsive operational approaches to thrive. These influences include but are not limited to overall population growth, inner-city revitalization, increasingly distant daily commuting destinations, pervasive highway congestion, rising fuel prices, economic uncertainty and constricted access to capital for major infrastructure investment, improvement of

bus engines and fuel adaptability, expanding telecommunications capacity, and synergy in digital advances and dispatcher abilities.

There are further influences of a social and political nature. These feature the impetus for environmentally sounder, or sustainable, transportation solutions among urban, regional, and national planners. Also a factor is growing pragmatism on the part of elected officials at the local level when it comes to decision making, as evidenced by many progressive municipal ordinances—enacted regardless of the dominant political party affiliation of the locality—that encourage and invest in alternatives to non-sustainable energy, transport, and building methods.

Such changes and trends are evident in many parts of the world; it is not likely accidental or coincidental that numerous innovations in interurban and municipal bus systems have first been tested and refined in regions with less disposable income, fewer readily available resources, and less material abundance. Bus system innovation has been particularly marked in some of the developing world's major cities, such as Bogotá, Colombia; Quito, Ecuador; Lima, Peru; Curitiba, Brazil; and Guangzhou, China.

Researchers have pointed to the striking advantage bus operators have compared to transit systems that require considerable time and capital investment in infrastructure. Interurban bus systems can get up and running in a tiny fraction of the time it would take a rail operator, for example. Hand-in-glove with this advantage of speed to market, bus systems also have a fair amount of route flexibility built into their mode.

Bus systems in the interurban mode have some inherent advantages over automotive transport. Among these are a reduction in traffic congestion and the collective level of engine emissions, reduction in road accident fatalities, and the more general financial, environmental, and infrastructure benefits that flow from each of those reductions. The effective value of these advantages can often be enhanced by the use of such innovations as bus-only lanes, or busways. Road capacity is effectively increased in the case of some busways to levels that match rail capacity, as measured in terms of passenger-miles per minute. This is achieved by virtue of the average bus speed having increased and the average following distance being reduced safely and reliably through proper driver training, systems maintenance, and rule enforcement.

Passengers and Operators

There are several distinct types of key users of interurban bus systems. Among these are everyday commuters, business travelers, vacationers, social groups, immigrants seeking work or new communities in which to set down roots, persons for whom air or rail travel has become prohibitively expensive, and those individuals who do not drive private automobiles for reasons that may be economically or socially derived.

There are widely divergent profiles among the interurban bus line operating companies today. Long-established national and regional powerhouses have been through a period of great consolidation and robust growth of passenger volume—only to see market share erosion set in as newer, extremely low-cost operators have stepped into most markets to challenge the majors for interurban business. This last factor has led to considerable volatility in the marketplace. Other factors increasing the uncertainty of the business model include fuel prices, changing debt loads in a noninflationary macroeconomic environment, and the game-altering technological price-shopping ability of most customers.

Insofar as local and regional markets provide the opportunities, challenges, trends, and pressures that either attract or repel potential commercial route operators, they also can be influenced by the action of public policy planners and administrators. For-profit bus line operators must have suitable incentives or they will not long offer service in a given market. Urban planners, on the other hand, often have to answer the needs of underfunded constituents of their population, as well as face the specific policy challenges of residential and commercial land development, mandates to cut pollution, or make parkland accessible, and the myriad of other municipal demands.

Other Enhancements

An additional measure to increase the performance and satisfaction levels of interurban bus systems is to adopt the flexible route approach, in which dispatchers update drivers of critical traffic conditions and advise alternate roadway paths to their destinations. This ability has grown in recent years by virtue of combining global positioning system (GPS) data, real-time traffic update services, more closed-circuit television observation of highways and key intersections, and better station-to-bus communications.

Passenger psychology plays into many aspects of the acceptance and repeat utilization of interurban bus service. In case studies of some European and American bus operators, it has been demonstrated that consumer faith, trust, and comfort levels are improved when passengers have access to information such as length of wait for arrival or departure, road conditions, weather conditions at the various destinations, safety and security measures employed, and the availability of upcoming technological and transactional improvements in the bus service systems. These seemingly emotional measures, in fact, played a demonstrable role in affecting ridership and customer retention.

This in turn has larger ramifications, inasmuch as municipal planning organizations that gain confidence in the ability of bus operators to meet expectations of the riding and commuting public will be that much more ready and able to deepen partnerships with their counterparts in connecting cities, with decision making likely to shift to the advantage of interurban bus systems.

Secondary Service

While interurban bus systems in general work when their resources and efforts are concentrated on direct travel between city centers, some demographic trends suggest that flexibility may be rewarded in cases where constellations of exurban, smaller town center, and even rural crossroads locations are incorporated into the system, even if on an intermittent basis.

Adjustable fare schedules, on-call pickup requests trafficked through central system dispatching, real-time road conditions and congestion data availability, and other advances can make this option an advantageous add-on service for bus operators. Off-peak service could be blended with these secondary and even tertiary route stops, depending on how much of the available open seating on a given bus and a given route could be reasonably expected to be filled. It is likely that such a system extension would gain in potential viability by the use of collector shuttles or vans in some of the targeted sub-destination communities.

A trial-and-error approach and sufficient tolerance for initial break-even timeline extension may both be needed in order to fully gauge the ultimate success of such service, but there are reasons to consider that offering such an ancillary

tier of service would be beneficial both financially and in terms of augmenting political influence for the inevitable negotiations that come with system review by planning authorities and with infrastructure funding request cycles.

Transit-Oriented Development

One vital component of gaining and sustaining local support for interurban bus systems is the priority of keeping an adequate portion of the planners' attention fixed on the transit-oriented development (TOD) in the immediate neighborhoods surrounding the transit stations. TOD embodies both opportunity and risk. Done right, with appropriate and reasonable levels of community input as well as buy-in from outside parties interested in freshly investing in these districts, there can be fair expectation of reaching a sustainable, gradual improvement in the area from a residential, commercial, and cultural standpoint.

Of course, the sustainability of communities and infrastructure at each of the stations and transfer nodes of an interurban bus network is not a given—indeed, the goals must be clearly enumerated and then prudently considered in every stage of planning and execution. Experienced urban planners know that development around transit stations of any type does not automatically lead to economic revival or quality of life improvements in the vicinity of a new station. Nevertheless, the city neighborhood that avails itself of the opportunity today can draw upon a wealth of wisdom gained from many like projects previously pursued in varying urban environments and conditions elsewhere.

Some essential principles or strategies seem to have been proven in cases of successful TOD. These goals and instruments are sometimes summed up as the “ABCs of TOD zoning”: active, pedestrian-friendly streets, building intensity and scale, and careful transit integration. While the rule is not “one size fits all,” some locally sensitive iteration of these concepts can help get an interurban bus system off to a strong start. Each of these can be achieved through intelligent zoning, smart infrastructure investments, and commitment on the part of city authorities to provide the staffing and upkeep necessary for long-term success.

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See Also: Bus Information Systems; Bus Rapid Transit; Bus Rapid Transit, Design and Engineering; Busways and Reversible Bus Lanes; Jitneys; Privatization of Public Transit; Transit Centers.

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market, as riders' only choice was walking, which for many urban trips was not practical. This "supply side" logic still pervades some transit authorities, with a take-it-or-leave attitude, leading inevitably to riders getting a car and leaving buses for good.

Supply and Demand Side Considerations

In most developed cities, buses are no longer a vital service; indeed, service frequencies are often very low (hourly), a result of decades of adjusting to declining demand, as though bus services are unable to meet peoples' aspirations. This supply side logic often ends in poorly used service or none at all, the only question being how long it will take or how long subsidies will be paid for a service carrying so few people. For instance, in the United Kingdom (UK) pensioners have free bus travel, and they make up more than a third of passengers. However, most pensioner trips are not made by bus but by car.

A demand side approach is based on market research, looking at what incentives automobile users require to take some trips by transit. This is the approach that the sellers of all consumer products adopt, both to maximize sales to existing customers and also to find new products that non-users will buy. There is a considerable body of such market research, which shows that price is not the main driver for those with a choice but quality of transit service provided.

Would improving the quality of service, going "upmarket," be the obvious way to attract riders? Sadly, further market research shows that even if a bus service could be provided that offered immediate departures from bus stops, running nonstop to the desired destination, this would only attract a very small part of auto traffic. One such study in Galway in Ireland, where buses presently carry 4 percent of all city trips, showed that such a "perfect" bus service would raise this to 8 percent, leaving cars with over 60 percent of all travel.

Land Use and Transport Coordination

Logically, if land use development and bus service provision could be coordinated, then the use of bus services would be maximized. Such an experiment was conducted in Runcorn New Town, England, built in the 1960s, where a dedicated busway linked all developments with a 40-mile-per-hour (mph) (65 kilometers/hour) frequent bus service, and the freeways were arranged so that internal trips by car

Bus Systems, Local and Express

The term *bus* is short for *omnibus*, the Latin word meaning "for all." In fact, buses in most developed countries are not for all, due to market segmentation. Buses are for "dependent" riders, who do not have the option of using a car, either because the only family car is with the breadwinner at work or because there is no car. The social characteristics of bus users are that they typically come from the poorer strata of society. This was not always the case, nor is it now in developing countries; before universal car ownership, buses operated in a sellers'

would take longer than by bus. It was confidently predicted, when it was built in 1969, that buses would carry 50 percent of all internal Runcorn trips. The best managed was 15 percent, which did not justify a frequent service, so with increasing car ownership, buses now carry only 5 percent, no better than other UK towns without an expensive busway but higher than most North American cities.

Service Quality and Fares

As most bus services are provided by public authorities, political control often sees fares as the most important deterrent to using buses and the easiest variable to change, providing public funds will allow subsidy. Most market research shows that fares are usually the fourth, sometimes fifth, consideration behind reliability, speed, frequency, and convenience. These are all service quality characteristics, changing any of which usually requires investment or extra costs. Speeds and service frequency are interrelated. If buses can operate more quickly, the

same number of vehicles and crews can perform more journeys and so offer a more frequent service.

In spite of popular myths, traffic congestion is rarely the cause of bus service unreliability, since time at bus stops is longer and more variable than time at traffic stop lines. Getting passengers on and off buses faster is, like the supermarket queue, the best way to speed up service. The fastest speed is about two seconds per passenger. Where passengers on boarding have to check fares with the driver, this time can increase to 10 seconds, which means a minimum time of 12 seconds for six passengers expands to one minute.

Boarding time and the fare system interact. Early trolleybuses had two operators, a motorman and someone to collect the fare. One-person operation in the United States was introduced in the 1920s to reduce costs, as auto competition bit. This led to replacing fares based on distance traveled with a single flat fare, which was easier to collect. There is an economic justification for flat fares, namely, that



The Runcorn Busway outside of East Runcorn railway station in Cheshire, England, in 2010. When new, the busway reached a peak ridership of only 15 percent of those making local trips, rather than the anticipated 50 percent. It suggested that even faster trip times in comparison to automobiles would not lead to a significant increase in bus use. Similar experiences were reported in Houston, Texas.

nearly 80 percent of operating costs relate to stopping and starting. The most economical part of bus operation is cruising at a steady speed. Even faster are “flash” tickets for multiride or multiday validity. Most European systems operate multidoor boarding with ticketing on the “honor” system, backed up by random checking and a high charge for riding without a ticket.

Express Versus Local Services

Most bus services stop everywhere, although many systems operate on a request basis at some stops, so that buses only stop where passengers want to board or alight. The running timetable is drawn up to all for stopping at every stop. Not all stops have the same number of passengers boarding or alighting. Some stops are busy as they coincide with places of high-density activity, such as a college. If there are enough passengers to support a frequent service, for example every five minutes, then there is a case to have an express service only stop at the busiest stops. Thus a five-minute-frequency all-stops service can be converted into a 10-minute all-stops and five-minute express service, so that the busiest stops still get a bus more than once every five minutes.

In order to make the case for an express service to supplement an all-stops service, detailed passenger origin and destination data is needed to ensure that the maximum number of passengers benefit from the faster service without disadvantaging the remaining passengers using the less busy stops.

Bus Stop Spacing

There are many theories that advocate one plan of bus stop spacing over another. Since the purpose of a bus service is to attract and carry passengers, bus stop spacing is not just an operational matter. There is a trade-off between the time passengers are willing to spend walking to a bus stop and the time spent on the bus. Walking time to bus stops is shorter when stops are close together. Riding time is shorter when stops are farther apart. Since passengers weight walking time as being twice as onerous as riding time, this would produce close stop spacing, say every 300 yards (275 meters) or so, but slower service overall. An alternative to having dedicated stops is request-only service (where the driver stops wherever there is a passenger waiting to be picked up or wishes to be let off) which would minimize walk time, and minimize ride time.

Should bus stops have pull-ins off the roadway? Such “lay-bys,” while benefitting (a few) car drivers, inconvenience bus passengers, who are delayed as the bus driver tries to reenter the traffic stream. If public policy is in favor of bus transit, then there is no case for bus lay-bys, since if the service is infrequent, few car users will be inconvenienced by buses stopping in the traffic lane. If the service is frequent, then bus passengers will easily outnumber car users.

Operation and Timetables

One other factor influencing bus stop spacing is service frequency. With a high-frequency bus service, timetabling is critical, as is the method of fare collection. A slow fare collection system will lead to buses bunching, like the supermarket checkout line problem, and thus an unreliable service. As early as 1955 studies showed that with even a two-second boarding time, if passengers arrive faster than they can board, buses bunch. More stops, close together, spread passengers and reduce the problem of bunching and unreliable service. The operating timetable must also be framed to reflect passenger numbers as well as traffic conditions, because unrealistic timetables—not enough time in the peaks and too much time off peak—lead to unreliability. Finally, driver discipline is important to maintaining a reliable service, and one of the most important factors is leaving the terminus at the right time.

Revenue Collection Systems

Revenue collection may be a matter of public policy if the bus transit service is publicly or municipally owned and must be subsidized. In the UK, where most bus services were privatized in the 1980s, 80 percent operate without subsidy on a commercial basis. Since bus passengers in developed countries are “captive” but poor, the fare system may be operated as a form of social policy, with lower than economic fare levels. Nearly all such bus services now operate on a flat or nearly flat fare system if routes are long.

A cash fare collected on boarding is the slowest method and the most costly to process, as cash has to be transported, counted, and banked. As well as advance-purchase “flash” tickets, there are now contactless bank cards, which automatically debit the fare, and cell phones can be used to buy and

display tickets. All of these reduce or eliminate cash transactions on buses, which also improves driver security since the driver cannot be robbed.

Obviously, one benchmark for setting the fare level is the cost of operating the service, which is discussed below. Another benchmark is the (perceived) price of competitor transport, such as car or taxi. Nearly all bus systems offer discounts for regular travelers. While flat fares are easy to implement and police, they do impose a penalty on passengers who have to change buses to complete their journey, unless transfer tickets are issued. This is one reason why many European bus systems sell advance tickets by time, such as one hour, one day, one week, etc.; this allows passengers complete freedom to use several buses to make a journey without facing a fare penalty, and the allotted time is easily determined and proved.

For those operators who think this represents a loss of revenue, the alternative for many passengers would be not to make the journey by bus, so there would be no revenue, and outside the peaks, when there is spare capacity, the cost of carrying passengers at the margin is very low, so the revenue received from time-based tickets should cover this.

Finally, the elasticity of demand to fares historically has been about minus 0.3, which means that fare increases have always increased revenue, since the loss of passengers has always been less than the rise of fares. Today the evidence is that elasticity is minus 0.4 or more. This means that fare increases often do not increase revenue, as too many passengers quit using the service.

Operating Costs

The largest part of bus service operating costs is staff pay, typically 50 to 70 percent of total costs. Making drivers more productive from faster services and/or larger buses is one way to reduce unit costs. In the UK where bus services have been privatized, bus companies realized that raising fares to cover increasing costs only leads to going out of business, by driving away passengers. So UK bus companies have put a lot of effort into controlling and reducing operating costs.

In a bus service with high peaks, having a standard 8-hour work shift contract is almost the most expensive way to deploy staff. So, many UK bus companies have a mixture of full-time and part-time staff to cover peak demand and fleet operation.

Similarly, some companies have diversified into minibus operation to penetrate closer to passengers' homes, providing nearly a door-to-door service. Minibuses, being more maneuverable, can also offer faster service, and because minibuses are small, new drivers do not require the same qualifications needed for operating larger buses, and therefore can be employed at lower pay levels.

Fuel costs for diesel-engine buses is rarely more than 10 percent of operating costs but still a large ticket item. Good engine maintenance can optimize fuel consumption, but probably more effective is driver training, which has been shown to reduce fuel consumption by 25 percent. Less fuel used means less polluting emissions. Some bus operators have long-term contracts with fuel companies, while others buy on the spot market but need large storage tanks to benefit from low-price times. Many operators in Europe are also experimenting with recycled lubricating and cooking oils to improve sustainability and to be a little greener. Such non-diesel fuels tend to provide fewer miles per gallon but the gallons are less costly.

Depot Location

The main fixed operating plant for a bus service is the depot where buses are maintained, repaired, valeted, and garaged overnight. For a single busline the location of the depot will usually be at the end where most journeys in the morning originate, on a site that has low value and the depot is not seen as a bad neighbor. For a multiline bus system, this will be a more complex analysis, since each line will not need its own maintenance facility and one major repair depot may be enough for a city. Overnight garaging and valeting depots may serve one line or several lines and can be located at sites of low land value that may be in an industrial or commercial zone.

Bus Station or Dispersed Stops

Where a bus network serves a region or large city, there is merit in planning for a central bus station to facilitate interchanges between routes to enable "many-to-many" trips to be made. This, however, requires bus timetables to be coordinated, so that interchanging passengers do not have to wait, which would reduce the convenience and attraction of such trips. Interchange trips, however, are likely to be a minority, even if major trip-generating and -attracting activities are evenly spread throughout

the area. The reason for this is that most trips are relatively short and long trips relatively few.

A “central” bus station will need a large ground area to allow buses to enter, stop for passengers, and depart. If there are a large number of services with coordinated timetables, then there will have to be one bus stand for each service. In providing a central bus station, the relatively low-value economic activity of bus service passenger access and interchange can be enhanced by the development of air rights above the bus station for commercial or residential use. Such overhead development will need careful design to ensure that the bus station is not claustrophobic for passengers and staff and that adequate ventilation can be provided to maintain a healthy level of air quality by dispersing bus engine fumes.

The case for a central bus station weakens if the central business district (CBD) is itself the major destination of bus trips. In this case CBD bus stops can be dispersed in the downtown, and as an operational convenience two radial bus routes linked to make a cross-town route, so that buses are not required to wait in the city center for timetable maintenance and crew rests. Where bus services act as feeders to a rail rapid transit service, this interchange can be made very convenient by integrating the rail station with a bus station, including the possibility of cross-platform interchange.

Bus Lanes and Busways

Bus lanes and busways have been installed in many cities. These primarily provide supply-side benefits, in terms of faster running speeds, less traffic congestion and disruption, and therefore reduced unit operating costs. As discussed above, a pioneering experiment in Runcorn, England, to use busways offering faster trip times than automobiles, failed to achieve the anticipated improvement in bus use. Similar experiences were reported in Houston, Texas, where a 10-year program of high occupancy vehicle (HOV) lane construction reduced transit’s modal share by 10 percent. In contrast bus lanes and busways in developing countries report high use, for example, in Curitiba in Brazil, where car ownership is lower than in developed countries. It will be of interest to see if high bus usage is maintained when car ownership reaches North American, or even European levels.

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See Also: Bus Routes; Bus Scheduling; Bus Stops/ Shelters; Bus Systems, Interurban; Bus Systems, Rural; Buses; Busways and Reversible Bus Lanes; Transit Fares; Transit Fares, Media and Collection Systems and; Transit Systems.

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Bus Systems, Rural

Rural poverty can have a particularly debilitating effect compared to urban poverty in that it also leads to personal isolation and the inability to access public services. Those who are not poor can also suffer from these problems when they do not have personal transportation, which might occur because of health or age issues or personal preference. There is a need, therefore, for low-cost transportation to serve people in these categories and to make small-town living practical for many communities—people cannot buy products from local businesses if they need to visit the premises and are unable to do so. Rural bus systems are important in sustaining the populations in these areas and, to common with all public transportation systems, have a role to play in reducing carbon emissions and air and noise pollution.

Since speed is rarely a major factor in such services, rural bus systems can be a safer means of transportation while also being suitable for use of vehicles using renewable or low-oil sources. The problem posed for such services is, of course, the cost issue. The numbers of people wishing to use the service tends to be small and so the revenue that can be raised is limited. Further, there is a

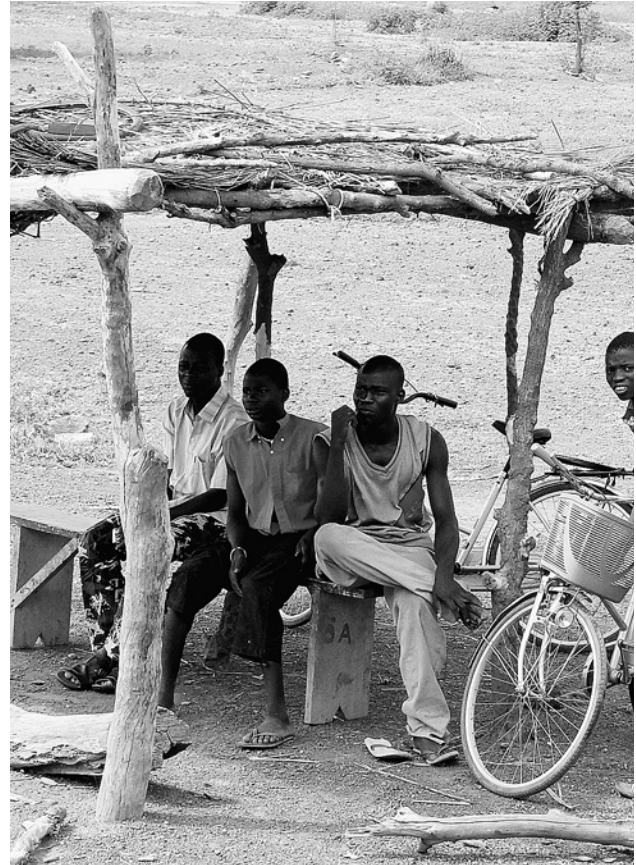
tendency for most customers to wish to travel from their homes to a local center and back again. However, routing logistics mean that buses customarily move from stop to stop in a geographically coherent manner rather than repeatedly to and from the central point. This means journeys tend to be lengthy and meandering and makes timing problematic because the distance between stops is directly related to the overall length of the journey; if passengers at every stop are to reach the central point at a time when they can access public services conveniently, then at least some of them will have to leave early or return home late.

In an era in which private wealth is preferred to public solidarity in most of the Western world, bus services of this sort tend to be starved of funds and the level of satisfaction suffers, leading to lower usage and then more cutbacks.

Governance Systems

The standard and most typical means of organizing a rural bus system is through the public sector, not so much because road transportation is a natural monopoly as because a regular and well-regulated service aiming to satisfy all communities is unlikely to be profitable. However, especially in less developed countries, there are numerous examples of private-sector operations. These operations tend to be underregulated and passengers may be placed in unsafe conditions. In rural Thailand and Laos, bus owners—these vehicles are usually small trucks or pickup vans with two rows of seating installed lengthways—roam from village to village based on local knowledge of periodically held markets and the needs of specific local people. They collect fees in cash only and have no obligation to visit a particular route or to adhere to any specific schedule. Even quite large operations, which drive large coaches from city to city, reserve the right to vary their advertised routes to other stops or cities if drivers feel they can obtain more passengers that way.

It is not coincidental that, across the developing world, road traffic accidents involving private-sector operators take thousands of lives every year. However, this does not mean that all private-sector operations are necessarily dangerous or otherwise improperly managed. Well-regulated private-sector operations do work quite satisfactorily in many countries.



Passengers wait at a handmade wooden bus shelter outside a village on the road to Dori, Burkina Faso, in July 2010. In less developed countries, passengers may often be subjected to unsafe conditions and unreliable schedules by private operators.

Alternative governance systems also exist. In the United States, for example, some schemes enable users to provide transportation services on a barter basis, that is, offering lifts to people in one area so that other people elsewhere (perhaps aged relatives) can claim trips of their own. There are some issues to deal with concerning insurance and safety in this case and there are other ways of organizing payment on a noncash basis.

One aspect of rural service that is distinctive is that it enables repeated human contact between service providers and customers and, as a result, personal relationships can develop such that bus drivers will look out for particular passengers, giving them additional time to board and alight if necessary and even involve themselves in some personal errands. This type of relationship used to be a more common feature in the past, when delivery

people such as mail carriers might have represented an important link between people in rural settings and the wider community. These are relationships that were ended by such factors as the imposition of more stringent productivity and efficiency approaches to the work completed by people in such jobs. It has been argued that the existence and fostering of such relationships plays an important part in the production and reproduction of harmonious social relations that contribute to the quality of life for those involved.

It is because, in part, of these positive externalities that various state or regional-level government agencies have been searching for alternative means of boosting demand in rural communities, thereby helping make systems operationally profitable. In Germany, one such effort is focusing on a “call-a-bus” approach, in which passengers can order a bus to stop to collect them or to deliver small packages for them. Since smart scheduling of such a service, provided sufficient capacity is available, can take advantage of off-peak hours when demand is low, it may be able to provide door-to-door service, which contributes positively to social capital while also reducing environmental degradation and pollution. Autonomous (that is, self-driving) vehicles can be used to reduce costs, and the vehicles employed could run on less environmentally damaging energy sources such as batteries or solar power.

This system will likely become more viable if the desire for localism develops further, so that people resolve to consume food and other goods and services produced within about 30 miles (50 kilometers) from where they live. Such a development would enable bus managers to bundle more of the services currently provided by specialized firms as a means of improving triple-bottom-line efficiency (that is, incorporating social and economic impacts into the accounting process). This approach is the opposite of what has taken place since the late 1970s, when deregulation and marketization of all aspects of contemporary life have become the norm, irrespective of the broader results of such changes.

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See Also: Bus Routes; Bus Scheduling; Bus Systems, Interurban; Bus Systems, Local and Express; Buses; Social Equity and Discrimination in Transportation.

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Buses

A bus is a self-propelled form of transit by road, which normally runs on a fixed route and schedule, serves identified stops, and is usually capable of carrying 10 passengers or more for a fare. Short for “omnibus,” it is sometimes used interchangeably with “coach,” although coaches tend to cover longer distances, have more room for luggage, require prepaid tickets, and have more comfortable seating. Sometimes charter bus services transport groups to a prearranged destination at a time of their selection, presenting an alternative to the fixed-route service that buses tend to offer.

Across Europe and North America, buses progressed from horse-drawn coaches and developed as a supplement to urban streetcars in the 1920s, and then eventually as a replacement. Bus networks saw a huge expansion in the 1940s through to the 1960s as a result of suburbanization, which saw the subsequent extension of road and highway networks and the demand for access to city centers and employment opportunities. They are now one

of the most commonly used forms of public transit. They are low cost and are most regularly associated with the young, students, women, the elderly, and people with low incomes. This can often include recent immigrants or ethnic minorities and as a result, bus spaces are regularly considered to be sites where boundaries of class, race, and ethnicity are “breached.” On the presentation of an ID card and bus pass, the elderly and students are commonly entitled to free or discounted travel.

Transportation by bus is often done out of necessity and is a method of travel that is often considered to be a last resort, associated with short journeys and commutes. Unlike travel by automobile, which is considered to offer more security and connotations of prestige, competence, speed, masculinity, skill, and autonomy, buses require that passengers travel in close proximity to strangers and are often considered to be both less comfortable and a slower form of travel. They are regularly associated with problems of overcrowding. In most circumstances there are no seat reservations, and although buses operate on a timetable, there are often no real travel-time guarantees. Unlike trains, for example, they are susceptible to the problems of urban congestion and are often slowed down by the need to distribute tickets to boarding passengers—although this is not the case with all services. Methods of payment vary considerably. If paying by cash, in some instances, the exact amount is required, as no change is provided in order to keep boarding time to a minimum. Passes can be purchased for a day of travel, a week, or longer and are usually shown to the driver, swiped, or tapped upon boarding the bus. Local boarding and payment procedures are likely to vary considerably and have been cited as one reason why bus travel is avoided by some people.

Contemporary buses have no conductors and there is often little space for luggage, although there is often a designated area at the front of the bus for large bags and shopping. Unlike other forms of transport, buses are likely to make more regular stops and can stop every few minutes. As a consequence, bus passenger groups constantly change and passengers might be required to swap seats as people get on and off, to allow less able passengers or people with buggies or luggage to sit near the front. Passengers wait at bus stops or bus shelters that display the number of the bus route they

require, as stops often serve as collection points for more than one bus service or provider.

In order to address the adequacy of bus services, cost and efficiency are often considered to be the key factors affecting user choices of transportation. However, in recent years, attention has been paid to the experience of bus travel in an effort to increase public use of buses beyond low-income groups. This is important to transport policy, as buses are increasingly seen as a solution to promoting more sustainable forms of transportation and to reducing the number of automobiles on the road.

It is widely recognized that bus travel can often have a negative reputation as a focal point of danger. This includes concerns about antisocial behavior from other passengers, vandalism, and also drug taking and drinking during journeys. It is commonplace for buses to have security cameras on board as well as sophisticated systems for reporting vandalism and antisocial behavior. However, due to the lack of onboard conductors and the design and layout of buses (double-deck buses in particular), it is often felt that these measures are insufficient to secure the safety of passengers. Concerns over security are particularly prevalent at night and are also associated with waiting alone at bus stops for long periods of time.

Alongside fears over security, the close proximity to other people that is required during bus travel is often considered to be another factor that makes buses an undesirable form of transportation. This includes a lack, or invasion of, personal space and the use of mobile phones and other mobile technology devices that are regularly cited as sources of conflict and annoyance. Despite frequent complaints, however, it should be noted that buses are also considered to be spaces of conversation and social connection and have been prioritized within urban public policies concerned with tackling segregation as a way of moving people between different areas.

Types of Buses

The most common form of bus travel is the scheduled route service that often operates within and between urban areas and is characterized by frequent departure times. City and suburban buses tend to have a low maximum speed, make regular stops, have maximum provision for standing passengers, and have a low provision for luggage

storage. They can be accessed from the curbside by two or one access points.

Tour buses often follow a specified circuit and may run on a regular schedule depending on the season. These can often be seen within urban areas and take tourists to key sites and tourist locations. Tour buses may be open top and accompanied by a tour guide. Some tour buses might provide intercity services and have a larger capacity for storage.

School buses transport children between home and school and are used only by school pupils. While yellow school buses are commonplace in North America, across Europe the prevalence of school buses varies, and in some countries the travel requirements of schoolchildren might be met by regular fixed-route services.

Finally, airport buses often link airports to downtowns or urban transport hubs such as train stations to enable passengers to gain access to further transport networks and to make connections for onward travel. These bus services are sometimes provided free of charge and have a much larger capacity for luggage storage and low-ride platforms. Bus design varies considerably. They can be either single-deck or double-deck, although double-deck buses are more commonly associated with urban route services. Other noticeable designs include the “bendy” or “articulated” bus, which can bend in the middle to accommodate a large number of passengers while still being able to navigate compact road networks.

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See Also: Accessibility and Mobility; Bus Routes; Bus Scheduling; Bus Systems, Interurban; Bus Systems, Local and Express; Bus Systems, Rural; Commuter Buses; School Buses.

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Business Travel

Business travel is a significant and substantial force in the U.S. economy. One out of eight U.S. jobs depends on travel and tourism, and travel is among the top 10 employment industries in 48 states. Business travel directly sustains more employment than a host of other key U.S. economic sectors. The 1.92 million jobs created by business travel spending exceed employment in building construction, food manufacturing, computer and electronics manufacturing, telecommunications, chemical manufacturing, oil and gas extraction, and motor vehicle and parts manufacturing.

Economic Effects

Business travel alone accounted for \$249 billion spent in 2011 by domestic and international travelers in the United States. Business travel expenditures include transportation to, overnight lodging at, and food consumption during all business meetings, events (such as trade shows), and incentive trips.

Corporate spending on travel may include air and rail transport, taxis, car rentals, hotels, restaurants, and event planning. All of these and related expenditures represent the direct impact of business travel spending on the economy. Less direct—but no less valuable—is the broadening effect business travel has on company performance and productivity, as well as the longer term effects on the economy as a whole. These indirect gains may include staff and customer retention, broader customer market, employee satisfaction and performance, idea sharing, industry knowledge and growth, improved products and services, and building of corporate relationships. Not as easy to measure but nonetheless one of the more important aspects of business travel is preventing the potential loss of current customers and revenue from *not* meeting in person.

Trends and Impact

A May 2013 report from Oxford Economics, a global research firm, provided clear evidence that business travel directly leads to an increase in both corporate revenue and profits.

The study found that for every dollar invested in business travel, the return on investment (ROI) resulted in averages of \$12.50 in added revenues and \$3.80 in new profits. Trip types with the highest returns were customer meetings, followed by

conferences and trade shows. Other findings in the Oxford report indicated that although business travel declined during the 2008–09 economic downturn (during the first two months of 2009, the U.S. lodging industry alone lost more than \$1 billion in revenue from the cancellation of corporate meetings and events), business trips increased from 2010 through 2012 and were still on the rise. Data from 2007 through 2011 for 61 industries showed that sectors spending the most on business travel through the recession tended to exhibit profit growth through the latest economic cycle.

Companies depend on face-to-face meetings to close deals, to keep present customers as well as win over new business, and to develop high-performing employees. Surveys taken as part of the Oxford study showed that business travelers believe that over 40 percent of customers would eventually be lost without face-to-face meetings; they believe that prospects are nearly twice as likely to become new customers with an in-person encounter than without one. A survey of business executives at companies with more than \$50 million in annual sales found that of those surveyed, 82 percent believe that business travel is important to achieving their business results, 81 percent believe that more client contact is necessary in a slow economy, 59 percent strongly agree that in-person meetings grow their business, and 72 percent believe that increasing travel while others are cutting back creates an opportunity to build market share and new customer relationships.

Global View

As reported in May 2011 by the World Travel and Tourism Council (WTTC) in a two-pronged study, business travel over the past decade has improved global corporate productivity 10-fold and created millions of jobs worldwide. Business travel is integral to international trade, and it is estimated that one-third of global trade over the past decade has been driven by international business travel. In the first part of the WTTC study, a survey taken of 500 global business travelers and executives from the United States, the United Kingdom, Germany, Brazil, and China revealed a clear link between international business travel growth and growth in world trade. Results from all five countries indicated clear benefits in terms of new sales, increased profits, innovation, partnership opportunities, and overall productivity and efficiency.

In the second part of the study, an econometric analysis was undertaken with data covering 190 countries. The modeling tested for the existence of any causal relationships between business travel and national economic performance. Results indicated that countries with a larger level of business travel spending tend to experience a higher volume of exports. Also, faster growth in business travel is linked to more rapid trade growth.

The implications of these trade effects are significant. Trade not only generates income for companies but also advances economic development by creating operational efficiencies, lowering prices, allowing countries to gain in terms of comparative advantage, encouraging innovation and creating competition. As business travel plays a role as a catalyst of global trade, it spurs global economic growth and stability.

Concerns

While there is much data supporting all of the benefits of global business travel, this economic sector is not without some inherent difficulties. Even as national economies recover, corporations are tentative about travel spending. Virtual meeting technology, increased fuel and environmental costs, and security concerns are all influencing corporate and government policies concerning travel. As an example, in his May 7, 2013, report to the U.S. House Subcommittee on Commerce, Manufacturing, and Trade, Roger Dow, president and chief executive officer of the U.S. Travel Association, pointed out that the main obstacle presently discouraging travel (both business and leisure) into the United States from abroad is an inefficient entry process (long lines and wait times). Aviation security systems are currently developing new approaches that have a greater level of efficiency while maintaining security.

Meetings and events held both in person and online (“hybrid events”) will be increasingly explored by more companies as a way to control costs while taking advantage of social features offered by new technologies. Despite these new innovations in virtual technology, many business executives still firmly believe in investing in face-to-face contacts. In-person encounters are the foundation of business travel economics.

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See Also: Air Travel; Economic Development; Security, Transportation.

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Busways and Reversible Bus Lanes

Busways (also known as "bus lanes") are road lanes for the exclusive use of buses. In some cases or at certain hours of the day, other vehicles may also be allowed to use the lanes. Busways are increasingly relevant in transportation policy as an instrument to reduce car use and tackle problems such as congestion, road safety, pollution, and energy consumption. Bus lanes are also implemented as elements of high-performance public transportation networks such as bus rapid transit (BRT) systems.

Despite the advantages and the increased relevance of busways in urban transportation policy, the implementation and operation of the schemes are sometimes restricted by a lack of social and political support and by problems in enforcement.

Busways were first used in Germany in the 1960s, with Hamburg being the first example. Cities throughout the world have since implemented the system in parts of their bus network. In large metropolitan areas such as London, Paris, and Beijing, the network of busways is very extensive (more than 200 kilometers long) and fulfills a crucial role in the mobility of commuters. Busway schemes have generally met with success and are increasingly considered as an essential element of programs to mitigate road traffic and improve the performance of public transportation systems.

While the system is designed for the exclusive use of buses, other vehicle categories, such as motorcycles, bicycles, delivery vehicles, emergency vehicles, taxis, and other means of public transportation are sometimes allowed to use the lanes. Buses may also share the lanes with cars traveling with more than one or two passengers in schemes known as high occupancy vehicle (HOV) lanes or high occupancy toll (HOT) lanes. In some cases, busways are open to all road traffic during off-peak periods. Some lanes may also operate in both directions depending on the time of day and are known as reversible lanes. These regulations ensure a more efficient use of road capacity in the cases when demand is highly variable throughout the day, such as in commuting corridors linking residential areas with major centers of employment.

The implementation of busways may be complemented with other preferential measures for buses in road traffic, such as the assignment of signal priority, queue bypass or queue jump, and turn restriction exemptions. These measures are applied to increase the connectivity of the lanes for the exclusive use of buses and to reduce delays in bus services by eliminating detours and stops.

Objectives

The main objective of busways is to increase the average operating speeds for buses in areas with high congestion levels. Indeed, the assessment of the effects of the scheme in cities throughout the world has consistently shown substantial improvement in the speeds of bus services operating along the busway corridors. The use of busways is especially attractive to express services, although they also bring advantages to services stopping at every bus stop, especially when structures such as curb

extensions and boarding islands are included in the design of the system.

However, the improvements in bus lanes may come at the expense of speeds in other parts of the bus network, especially when the lanes are implemented through the reallocation of existing road space. The reduction of capacity for general traffic reduces its average speeds and may force some car drivers to use alternative routes. If capacity along these routes remains unchanged, congestion will increase, affecting both car and bus traffic.

The reduction of congestion levels in bus lanes brings additional advantages apart from the effects on speed. Users benefit from the increased reliability of the services, due to the reduction of delays and lower variability in waiting times at bus stops. The operators of the system also gain financial benefits as congestion is usually related to higher fuel consumption per distance traveled due to vehicle idling time. If the improvement in the performance of the bus system attracts additional passengers, revenues will also increase.

Advantages

A series of indirect advantages have also been identified. By making bus travel more attractive, the system promotes modal shift from private vehicles, contributing to a general reduction in road traffic levels, congestion, and emission of local and global pollutants. The existence of bus lanes also contributes to a reduction in the number of fatalities in road accidents, as they act as a buffer reducing collisions between vehicles and roadside objects. In addition, the separation of bus and car traffic enhances the safety and comfort of passengers waiting for or boarding buses, as it increases the visibility of buses and increases the distance between passengers and cars.

Disadvantages

Nevertheless, busways can also have a negative impact on pedestrian safety and local environmental conditions when the implementation of the scheme involves the construction of additional lanes. The widening of the road may be achieved by reducing pavement space. This increases the proximity of pedestrians to road traffic, with effects on pedestrian accident risk and exposure to air pollution and noise. The increase in the number of lanes also affects the safety of pedestrians crossing

the road. The widening of the road may also come at the expense of existing open space surrounding the road, with indirect effects on urban environmental conditions.

Bus Rapid Transit and Other Strategies

Busways are an essential component of policies to improve the performance of urban public transit networks, such as the implementation of bus rapid transit systems. These systems share some of the characteristics of light rail or underground systems, such as a limited number of stops, frequent and regular service, and the use of exclusive corridors. The success of BRT systems in Latin American cities such as Curitiba (Brazil) and Bogotá (Colombia) has encouraged the adoption of similar systems in other cities of the world, with a large number of systems currently being developed in China and India.



A tour bus followed by a sport utility vehicle in a single-direction bus lane on Broadway in Lower Manhattan. The city of Hamburg, Germany, pioneered bus lanes in the 1960s and has since been followed by large cities around the world.

Busways are also increasingly planned as a part of broad strategies for the promotion of alternatives to the use of private vehicles. As such, some busways are designed or redesigned for the shared use of buses and bicycles. These projects can increase the efficiency in the allocation of road capacity to different means of transport. They can also decrease accident risk for cyclists by separating them from general traffic. However, the achievement of these objectives is dependent on careful design and control of several elements of the road and of the bus system, such as lane width, bus speeds, locations of bus stops, clarity of traffic signs, and design of intersections.

Reception

Despite the obvious advantages of the scheme, transport authorities do not always gather the social and political support needed for the expansion of the busway network. Car users may object to a perceived preferential treatment of users of public transportation. This is especially prevalent in cases in which bus lanes are underutilized. In addition, when busways are implemented through the reassignment of existing road space, congestion may increase considerably in the other lanes, leading to losses of time and higher fuel consumption for car users.

Bus lanes can also reduce space available for car parking and space used for loading and unloading freight. There are also conflicts over which vehicles other than buses are allowed to use the lanes. This is often the case when access to taxis is granted to a select number of taxi firms, leading to complaints

by the other firms on the grounds of distorted competition.

The system can also meet with problems at the operational level. Given the extension of most busway networks, the enforcement of restrictions on the use of the lanes is difficult and costly. Failures in enforcement may lead to reduced speeds when a large number of private vehicles use the busways, and to bottlenecks when parked cars obstruct the lanes. The problem is sometimes addressed by using barriers to separate bus lanes from other lanes. The increased use of closed circuit television can also improve enforcement by dissuading car drivers from using the busways.

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See Also: Bikeways/Bike Lanes, Road Design Issues of; Bus Rapid Transit; Bus Rapid Transit, Design and Engineering of; Bus Systems, Interurban; Bus Systems, Local and Express; High Occupancy Vehicle Lanes; Traffic Control Devices.

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Cable Cars

Cable cars are a type of railway consisting of a continuously moving cable and a number of cars that are powered by gripping onto the cable; in order to stop, the cable is released and a brake applied. In the 19th and early 20th centuries, cable cars (often called cable tramways or cable trams, to distinguish them from funicular railways, which are permanently attached to their cable) were one of several means of providing streetcar service in major cities. Advantages of cable cars include their ability to climb steep hills, their lack of pollution, and their relative impermeability to extremes of weather. However, other methods of public transportation, including electric railways and buses, eventually replaced most of these cable tram systems. The only city operating a traditional cable car system today is San Francisco, California, where cable cars are well adapted to the city's steep hills and are keeping part of the city's history alive.

Technology

A cable car system is propelled by a continuously moving cable that runs through a powerhouse, where it is threaded through a series of sheaves (wheels with grooves in their edges) powered by engines that impart the movement to the cable. The cables run out of the powerhouse and along their routes, encased in a protective steel "slot" below street level while the

cable cars run on rails above it. The cable cars have no power of their own but are moved by the cable; thus they maintain a constant speed except when coming to a stop. Several different technological solutions evolved to enable an operator to grip and release the cable, and the cars also had several braking systems to further control the speed of the cars and allow them to be halted, one advantage of the cable trams over horse railways. Other advantages include the fact that the cable system is little affected by changes in temperature or by the accumulation of snow and ice and does not create pollution on its route. (It does, of course, at the powerhouse.)

Public Transportation

The city most identified with the cable car is San Francisco, California, where cable cars were invented, and the only city in the world where traditional grip-and-release cable cars are in use today. Andrew Smith Hallidie began construction of a cable car line in San Francisco in 1873, reportedly motivated by seeing a team of horses drawing a rail car slip and fall to their deaths. He may also have been motivated by the fact that a cable car system would use large quantities of wire cable, a product for which he and his father held several patents. Hallidie's cable car network began operation that same year with a single line, the Clay Street Hill Railroad, but by 1889 San Francisco's cable car network had grown to include 53 miles of track. By that time a second company, the Sutter Street



A cable car reaches the top of a hill near San Francisco, California's Chinatown in 2006. San Francisco is the last city in the world to operate a traditional cable car system.

Railroad Company, was in the cable car business; the Sutter Street Company originally provided transportation by horsecar, but it had converted most of its lines to run on cables by 1879.

By the turn of the century, electric streetcars were competing with the cable cars, although the steep topography of San Francisco gave cable cars an advantage on some routes. Cable cars were almost eliminated from the city in 1947 due to their higher operational costs relative to other forms of transportation but were eventually retained, in part because of their tourism value.

Sydney, Australia, included a few cable cars in its public transportation to provide transportation over particularly steep routes. However, Melbourne was the only city in Australia to create an extensive network of cable cars; the Melbourne system was the fourth-largest in the world, with about 75 kilometers of track, and operated from 1885 to 1940. Each tram consisted of two cars: a standard passenger car and a forward car called a "dummy," which pulled the second car; the driver, who operated levers to grip

and release the cable, rode in the dummy car. After the state government took over the system in the 1920s, Melbourne's cable trams began to be replaced by electric tram lines, and the last cable tram ran on October 26, 1940. In New Zealand, the cities of Dunedin and Wellington also had cable tram systems that are no longer in operation.

Many other cities operated cable tramways in the late 19th and early 20th centuries, usually alongside other forms of public transportation. Edinburgh, Scotland, had an extensive network of tramways that included cable cars alongside other modes of transportation; the last cable tram closed down in 1923. Glasgow, Scotland, had an underground cable tramway system from 1896 to 1935. Paris operated a combination funicular and tramway from 1891 to 1935, providing service to the neighborhood of Belleville, which was built on a steep hill. Chicago had a cable tram system from 1882 to 1913; although the city is largely flat, it has severe winters, and the fact that the cable cars were little affected by weather was an advantage. Seattle, Washington, a city with extremely steep hills, operated a cable car system from 1888 to 1940, making it the last U.S. city other than San Francisco to keep a cable car system in operation.

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See Also: Aerial Tramways; Funicular Railways; Rail Transit Planning, U.S.; Rail Transit Planning, Worldwide; Streetcars/Trolleys; Tramways; Transit Systems; Urban Sprawl Versus Compact Development.

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Canals and Locks

A canal is an artificial waterway built with the purpose of moving ships, goods, and/or people. The term can refer to an inland waterway that allows for intra- or inter-urban transportation, such as those in Venice, Suzhou, and throughout the Low Countries. Alternatively, it may refer to an artificial channel that connects two previously unconnected bodies of water.

The first examples of canals date back to pre-modern times. Mesopotamian societies dug canals for irrigation and flood control as early as the 4th or 5th millennium B.C.E. Evidence of irrigation canals by Indus Valley, Nile Valley, Sumerian, and Inca civilizations is also available, and the existence of an extensive network of canals under the Roman Empire is confirmed by the remnants of stone aqueducts found throughout southern Europe. China's Grand Canal, which connects the cities of Beijing and Hangzhou, was commenced in the 5th century B.C.E. and completed in the 7th century C.E. and remains the world's longest artificial waterway. From the outset, the Grand Canal has been a significant artery of commerce in China and remains so to this day.

On a relatively small scale, canal traffic has been an integral component of overland goods transport in Asia and Europe for over a millennium. However, the Industrial Revolution was the impetus for the large-scale expansion of canals throughout Europe and North America in the late 18th and early 19th centuries. Though Europe's canal network was initially better formed, the westward expansion of the United States' population drove the development of numerous canals, such as the Erie Canal and the Chesapeake & Ohio, which in turn dramatically reduced commercial transport costs. This system of internal waterways led to the early growth and development of several major cities, including Buffalo and Chicago.

However, as railways began to undermine waterborne modes of overland transport, many canals began to lose their commercial utility. The most significant canals of today are those that play a key role in global shipping, such as Egypt's Suez Canal, which connects the Indian Ocean basin to the Atlantic basin, and the Panama Canal, which connects the Pacific Ocean to the Caribbean basin and ultimately the Atlantic. While the completion of major

transcontinental railroads and highways has all but replaced intracontinental ship traffic, globalization and an increasingly spatially fragmented division of labor ensure that intercontinental maritime traffic has increased greatly, particularly in the wake of the formation of the World Trade Organization (WTO) and the advent of containerization.

Locks

A lock is an enclosed chamber used for elevating or lowering boats within a waterway. The purpose of a lock is to allow the construction of canals where changes in elevation, tidal variation, or differences in elevation (for canals connecting two bodies of water), would otherwise preclude them. In the process of elevating a ship, a vessel moves inside the lock and once its gates are shut, the chamber fills with water, either by gravity-fed or pump-fed delivery mechanisms. The vessel rises along with the water level, and after it reaches the height of the adjacent chamber or waterway, lock gates on the opposite end open and it carries onward. In lowering ships, the process is the inverse: once the chamber gates are closed, water is slowly drained from the lock.

In terms of influencing global commerce, the size of the world's major locks often determines the dimensions of international shipping fleets. Notably, "Panamax," "Suezmax," and "Seawaymax" refer to the maximum length, beam, and draft of vessels able to enter the Panama Canal, Suez Canal, and Saint Lawrence Seaway, respectively.

Condition

Many large-scale ship canals serve a vital role in global commerce. However, with the sweeping changes that shifted intracontinental commercial traffic from waterborne vessels to road and rail transport, many of the world's small-scale canals have been relegated to historical artifacts. While these generally remain functional canals, their utility is often primarily in terms of recreational boating, historical preservation, and/or tourism, and many cities and regions have benefited from well-preserved canal systems. India's Kerala province, China's Guangxi province, and Russia's St. Petersburg are all major tourist destinations within their respective countries, all featuring unique historic canal systems. In terms of recreation, extensive "canal boating" takes place throughout Europe,



A series of small locks on the Rideau Canal in Ottawa, Canada, in 2011. The canal is the oldest in continuous use in North America. Small-scale historic canals and locks such as this often no longer serve the crucial role in transportation they once did.

and more recently, many master-planned communities have been built around artificial waterways in the U.S. state of Florida and the Australian state of Queensland.

Expansion Issues

Given the increasing size of seafaring vessels, many ports, sea lanes, and canals worldwide are being augmented to accommodate larger ships. Construction is under way in the port of Antwerp, Belgium, for example, to build the world's largest lock. The most significant of these projects under way is the Panama Canal expansion. Approved through public referendum in 2006, the \$5.25 billion project is financed by a suite of international banks and institutions and will significantly increase the canal's throughput. When completed, the largest ships passing through the Panama Canal will have a maximum capacity of 12,500 20-foot equivalent units (TEUs), nearly a

threefold increase from 4,400 TEUs in the preexpansion era. This expansion has led to the enhancement of numerous port facilities around the world in order to handle "New Panamax" ships.

The expansion of the Panama Canal is being carried out in response to growing demand for transcontinental shipments. Although the Suez Canal and transcontinental rail transport are currently its most significant competitors, the Colombian and Chinese governments have proposed a "dry canal" to connect the Caribbean and Pacific by rail, and several Central American governments have announced similar plans, though nothing major has materialized.

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See Also: Containerization/Container Shipping; Inland Waterways, Freight Traffic and; Inland Waterways, Navigation of; Inland Waterways, Passenger Traffic and; Inland Waterways, Planning and; Inland Waterways, Traffic Management and.

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Car Sharing

The principle of car sharing is simple: individuals gain the benefits of private vehicle use without the costs and responsibilities of ownership. Instead of owning one or more vehicles, a household or business accesses a fleet of shared-use autos on an as-needed basis. Individuals gain access to vehicles by joining an organization that maintains a fleet of cars and light trucks in a network of locations. Vehicles are most frequently deployed from lots located in neighborhoods, at transit stations, or at businesses. Car sharing members typically pay for use through

hourly rates and subscription-access plans. Most car sharing operators manage their services with advanced technologies, which may include automated reservations, smart-card vehicle access, and real-time vehicle tracking.

Car sharing members have a variety of reasons for joining car sharing. Common reasons to join car sharing include the following:

- Environmental awareness
- Cost savings over owning a private vehicle
- Parking (maintaining vehicle access without the cost or difficulty of locating parking in an urban setting)
- Mobility insurance (access to a vehicle in case either a personal vehicle or commuting option is unavailable)
- Access to an additional vehicle (member who owns a primary vehicle and has a periodic need for a second or third vehicle but does not need to own an additional vehicle)
- Access to a vehicle on an as-needed basis (individuals selling a vehicle who retain a periodic need for a car and individuals without a vehicle who need periodic vehicle access)

Common goals among car sharing organizations include (1) reducing congestion and auto ownership; (2) providing cost savings since customers pay per use, sharing the costs of the vehicle lease, maintenance, repair, and insurance; (3) reducing emissions by lowering overall vehicle miles (kilometers) traveled and using clean fuel vehicles (for example, gasoline–electric hybrid cars); (4) facilitating more efficient land use (for example, car sharing reduces the number of parking spaces needed); and (5) increasing mobility options (for example, low-income market segment) and connectivity among transportation modes.

As car sharing has evolved, a number of niche markets have developed. A few of these include consumer car sharing, college/university car sharing, personal vehicle sharing (also known as P2P), and fleet-based services. In consumer car sharing, a company owns a fleet of vehicles to provide car sharing services for its members. College/university car sharing is very similar to consumer car sharing except that the car sharing operator's

goal is to provide vehicle access to university students (typically 18–25 years of age) and university staff and faculty. Personal vehicle sharing provides short-term access to privately owned vehicles. In personal vehicle sharing, private vehicle owners make their cars available for other drivers to rent. In fleet-based car sharing, government agencies and employers replace their own private fleets with car sharing services that can either be used exclusively as fleet cars or nonexclusively (fleet cars shared with ordinary car sharing users).

In addition to niche markets within car sharing, three different categories of operators provide car sharing services. These include automakers, rental brands, and car sharing brands. As of 2012, 10 automakers provided car sharing services or vehicles with factory-equipped telematics for car sharing. As of 2012, five rental-car brands were providing car sharing services worldwide. As of 2012, two automakers and three rental car brands were providing car sharing services in North America.

Types

In classic car sharing, a car sharing member joins an organization. Once approved, the car sharing organization typically sends its member an access mechanism (for example, smart card, key fob, etc.) used to access vehicles. Members typically go to the program's Web site to locate vehicles and select a model. Reservations can typically be made online or over the phone. When a member arrives for his/her reservation, the member unlocks the vehicle using the access mechanism.

Depending on the car sharing program, features may include open-ended bookings (that is, no fixed reservations), instant access (that is, no reservations), and one-way rentals (that is, vehicles can be returned to a different lot). Pricing also varies among programs. Some car sharing programs charge users based on length of time a vehicle is in use, distance-based fees based on cost per mile/kilometer, or a combination such as varying amounts of free mileage per an hour of use.

Shared-use services expanded into a new market segment, known as personal vehicle sharing (P2P), through the use of privately owned vehicles. In this model, personal vehicle sharing companies broker transactions among vehicle owners and renters by providing the organizational resources to facilitate these transactions (that is, online platform,

customer support, auto insurance, and technology). A few of the operators providing this type of service offer a hybrid car sharing service in which individuals have access to both private autos and a fleet of that operator's own vehicles. Additionally, new technologies are emerging that enable direct exchanges between individuals via the Internet (known as the "P2P marketplace").

Historical Overview

Car sharing became popularized in Europe in the mid- to late 1980s. Car sharing expanded to North America and Asia in the 1990s. Car sharing operations launched in Australia and South America in 2003 and 2009, respectively. In October 2012, there were nearly 1.8 million car sharing members worldwide, sharing approximately 43,500 vehicles. Of this, Europe and North America accounted for 39 percent and 51 percent of the worldwide membership, respectively. Asia accounted for 9 percent of the worldwide membership. Australia and South America collectively accounted for approximately 1 percent of the worldwide membership. As car sharing has evolved, phases of market development have become apparent, particularly in North America.

Phases of Car Sharing

In North America, car sharing evolution has progressed through three phases: initial entry and market experimentation (1994 to mid-2002), growth and market diversification (mid-2002 to late 2007), and commercial mainstreaming (late 2007 to present).

The first car sharing operators in North America modeled their operations after successful car sharing efforts in Europe during the late 1980s and early 1990s, focusing on neighborhood car sharing. The earliest Canadian operator, Auto-Com (now Communauto) was established in 1994. In the United States, CarSharing Portland became the first organization in 1998.

Initially, four major business models emerged: for-profit, nonprofit, cooperative, and university research programs. This early phase marked a wave of new entrants, technological development from manual operations to phone and Internet reservations, high-cost and difficulty locating insurance, and the first industry merger between Flexcar and CarSharing Portland in June 2001.

The second phase of carsharing reflected growing memberships, fleets, market diversification (for example, business car sharing, government fleets, and residential partnerships), capital investment, and multinational market entry. (Zipcar launched international operations in 2006.) By 2003, a number of car sharing organizations were operating in multiple regions, leading to new economies of scale and greater market penetration. Also in 2003, independent car sharing operators, including cooperatives, nonprofits, and for-profit organizations, formed an informal association.

Since 2003, interoperator collaboration increased, including the North American Code of Ethics for the Carsharing Industry (ratified by 20 operators, the majority nonprofit, in 2007), public policy collaboration, roaming memberships (members of one organization can submit their driving records to another organization to access their service), and technology development. The second phase was also marked by higher member-to-vehicle ratios, particularly in the United States, as operators sought to increase vehicle use and profitability to attract investors.

At the time, the merger of North America's two largest operators (Zipcar and Flexcar) marked the beginning of the commercial mainstreaming phase. Program mergers, the expansion of multinational operations, and market specialization have been notable characteristics of this phase. Some of these niche markets include the development of personal vehicle sharing, one-way car sharing, and the entry and expansion of both automakers and rental car brands into the car sharing marketplace.

In North America, U-Haul launched its car sharing service in May 2007, followed by Enterprise in February 2008, and Hertz in December 2008. Similarly, Daimler AG's car2go launched North American operations in May 2010, followed by BMW's DriveNow in June 2012. Other characteristics of this phase include ongoing market growth, interoperator collaboration, technological development, and a greater emphasis on public policy.

Impacts of Car Sharing

A number of social and environmental benefits are commonly associated with car sharing. The impact of car sharing can be categorized into transportation, environmental, land use, and social effects. A major impact of car sharing on the transportation system is a reduction in vehicle ownership. A

reduction in vehicle ownership, in turn, is likely to result in fewer vehicle miles or kilometers traveled (VMT/VKT), reduced traffic congestion and parking demand, and an increase in the use of public transportation and other transport modes (such as biking and walking) in lieu of car travel.

Estimates differ substantially between members who gave up vehicles after joining a car sharing program and those who gained vehicle access through car sharing. Car sharing also induces lower VMT/VKT by emphasizing variable driving costs, such as per-hour or mileage charges. Furthermore, reduced vehicle ownership and VMT/VKT lower greenhouse gas (GHG) emissions, as trips are shifted to transit, biking, and walking.

In addition, many car sharing organizations include low-emission vehicles, such as gasoline-electric hybrid cars, in their fleets. Car sharing members also report a higher degree of environmental awareness after joining a car sharing program. Finally, car sharing also shows evidence of beneficial social impact. Households can gain or maintain vehicle access without bearing the full costs of car ownership. Depending on location and organization, the maximum annual mileage up to which car sharing is more cost-effective than owning or leasing a personal vehicle lies between 6,214 to 10,000 miles. Low-income households and college students can also benefit from participating in car sharing.

Public Policy Considerations

A number of supportive and unsupportive policies have been implemented that impact car sharing. Generally, the majority of these public policies can be classified into five categories: (1) developer and zoning regulations, (2) fleet reduction, (3) parking policies, (4) risk-sharing, and (5) taxation.

In North America, policies have been developed to encourage car sharing in new developments. These policies include parking reduction (that is, downgrading the required number of spaces in a new development), parking substitution (that is, substituting general use parking for car sharing stalls, and allowing greater floor-to-area ratios (that is, developers can build more densely on-site).

A key component of fleet reduction policies is replacing a business or public agency's motor pool with car sharing services or supplementing peak demand of their motor pool with car sharing services (allowing for the retirement of underutilized



A car sharing vehicle in a dedicated parking space in Marburg, Germany, in 2009. Car sharing emerged in Europe in the 1980s. By 2012, Europe accounted for 39 percent of car sharing, North America for 51 percent, and Asia for 9 percent.

vehicles). The greatest number of public policies typically involve car sharing parking. These policies include (1) provision for on-street parking, (2) provisions for off-street parking, (3) exemption from parking limits, (4) creation of car sharing parking zones, (5) free or reduced cost for car sharing stalls, (6) free or reduced-cost parking permits, (7) universal parking permits (that is, car sharing vehicles can be returned to any on-street location), (8) formalized processes for assigning on-street parking spaces, and (9) use of parking meter revenue to subsidize car sharing.

Three common risk-sharing partners include local governments, universities, and property management firms. Methods of risk-sharing include (1) partnering with organizations to purchase membership blocks and/or guarantee vehicle use, (2) vehicle subsidies, and (3) the "subtraction model" whereby a car sharing operator values the monthly

cost of vehicle placement and subtracts monthly revenue from that collected value and bills the shortfall to the risk partner.

Common policies on taxation include local and state sales tax credits, exemptions from car rental taxes, tax credits to employers and property managers providing car sharing services, and the levying of special-use and/or sales taxes on car sharing services.

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See Also: Bicycle Sharing; Carpool Programs, Ride Sharing and; Carpooling; Carpooling, Casual; Shared Taxis.

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Carbon Dioxide Emissions

Few environmental issues facing short- and long-term transportation systems planners ignite more heated debate or more apocalyptic rhetoric than the role of steadily increasing carbon dioxide emissions in global temperature change. So-called greenhouse gases—naturally occurring atmospheric gases, among them methane, nitrous oxide, and most prominently carbon dioxide—act to absorb dangerously high levels of solar radiation, trapping it near Earth's surface rather than allowing it to escape harmlessly into the atmosphere. In turn, that contributes dramatically, according to a growing body of hard scientific data, to the phenomena of global warming and ultimately long-term climate change.

Carbon dioxide accounts for more than 80 percent of all greenhouse gases, and the increases in its production from human activity, most prominently the burning of fossil fuel to move virtually all types of vehicles, has raised significant challenges for those who design transportation systems, vehicle engines, and transportation routes. Concerted action is difficult as the problems are global. The scope of the transportation system in the United States alone is staggering: more than 3.9 million miles of paved roads; flights departing virtually every minute from more than 5,000 airports; 3.7 trillion tons of goods shipped domestically each year by truck, plane, train, and ship; one in eight jobs nationally tied to the transportation system. On any given day, close to 30 million children alone rely on buses for transportation to and from school.

Carbon dioxide itself is part of the natural activity of the carbon cycle; it is manufactured in a range of natural processes including photosynthesis, volcanic eruptions, and even breathing. Left to its own devices, nature largely balances out this carbon dioxide output, removing the gas most notably through its interaction with plants and trees that act as filters, and for the nearly 9,000 years of human presence on Earth that rhythm was largely maintained. However, in the two centuries of the Industrial Revolution, the output of carbon dioxide from unchecked human activity has significantly impacted the ability to control the emission levels.

Climate Change

Because research into climate change has become quite prolific over the last quarter century (thousands of reports issued annually, often with conflicting data) and because the argument of global warming has become a polarizing political issue (vocal arguments from the political right cast doubt on such scientific data and dismiss global warming itself as alarmist, antibusiness hand-wringing), it has been difficult to coalesce the argument for those who advocate stricter controls and better long-term transportation system planning not just within the United States (although the United States is second only to China in carbon dioxide emissions) but globally as well.

Although environmental researchers point to a variety of destructive human activities since the advent of the Industrial Revolution that have contributed to the problem—most prominently wide-scale indiscriminate deforestation and the combustion of fossil fuel to power more and more massive electrical plants—burning fossil fuels to maintain the global transportation system, including cars, planes, boats, and trains, is responsible for nearly a third of the total carbon dioxide emissions. More alarming, data indicates that in just 20 years, from 1990 to 2010, these carbon dioxide emissions have spiked more than 10 percent, a measure, advocates of long-term strategic transportation policy planning claim, of the evident failure of timid legislation intended to address energy consumption within the nation's transportation system.

Time for effective action is rapidly shrinking. In 2012, carbon dioxide emissions rose globally a record 1.4 percent, which scientists fear could set global temperature increases dangerously ahead of alarming predictions made barely a decade ago. Data that measures the cumulative volume of carbon dioxide in the atmosphere indicates that just two centuries ago carbon dioxide in the atmosphere measured less than 280 parts per million (ppm); in 2013 that number soared past 400 ppm for the first time in human history, a level long held to be a wake-up call for governments and businesses, underscoring the failure of public and private strategic transportation planning.

Reduction

The simplest way to address the problem with carbon dioxide emissions, of course, is collective

efforts to reduce the consumption of fossil fuels. It is not an exaggeration, scientists have argued, that every car trip, every cross-oceanic transport, every flight from crop dusters to jets, every turn around the lake in a powerboat ultimately registers in the amounts of carbon dioxide in the atmosphere.

Some progress has been made. The steadily escalating price of gasoline since 2000 (nearly doubling in price) has acted to depress the volume of driving as drivers conserve trips; share rides; pursue walking/cycling options; slow down; buy smaller, more fuel-efficient vehicles; and reorganize work schedules to allow work-at-home options or opt to live closer to work sites. But Department of the Interior data indicates that more than two-thirds of the vehicular transport in the United States alone is industrial, not personal: the vast transportation system makes accessible markets and materials to industries and such transportation needs cannot easily be downsized without dramatically impacting other sectors of the economy.

If regulating vehicle use poses too formidable a challenge, environmental advocates champion immediate and significant government and industry support for developing more fuel efficient vehicles that would use cleaner, renewable energy, such as hybrid models or electric cars that are currently too expensive and too inefficient for wide market acceptance. But economic uncertainties often drive increases in vehicle use; environmental researchers point to increasing distances workers must travel to accommodate job responsibilities; the relocating of families to follow economic opportunities; and car owners holding on longer to older, less fuel efficient vehicles, all of which, social and political scientists argue, points to the necessity of immediate local and state government long-term commitment to revitalizing the nation's crumbling infrastructure, giving drivers who must depend on their vehicles access to the quickest, most efficient routes. In addition, local governments could fund newer mass transit systems in high population centers.

Broader solutions involving other transportation systems that have been recommended by scientists have included redesigning the network of global shipping lines, drawing smarter, more direct routes despite political acrimony between and among nation states; revamping often antiquated railroad lines; developing lighter airplanes and phasing out older, heavier models; and maintaining air traffic

efficiency to minimize wait times on runways. However, environmental advocates largely agree that the most effective long-term strategy to control carbon dioxide emissions is to promote a radical (and across the board) change in vehicular driving habits.

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See Also: Air Pollution, Automobiles; Air Pollution/Air Quality; Alternative Automotive Fuels; Automobile Emissions Controls; Climate Change, Transportation Adaption to; Green Fuels.

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Carbon Monoxide Emissions

Carbon monoxide (CO) is an invisible and odorless gas that is toxic to humans in high concentrations and at long exposure durations. Carbon monoxide is produced naturally through photochemical reactions in the troposphere (lower atmosphere), and often produced as a by-product of incomplete fossil fuel combustion, such as burning coal to produce electricity or powering an internal combustion engine with gas, diesel, or natural gas fuel. In the latter case, CO comes from the unburned vehicle fuel released after combustion in engine cylinders. In the United States, this process is responsible for most CO emissions; the U.S. Environmental Protection Agency (EPA) estimates that

motorized vehicles produce around 86 percent of all CO nationwide. Of this total, on-road vehicles are responsible for 65 percent, nearly 90 percent coming from light-duty vehicles.

Regulation

Effective emissions regulation in developed countries has mostly eliminated the dangers of carbon monoxide emissions. Vehicle emissions control systems (for example, catalytic converters and electronic fuel injection systems) have evolved to meet increasingly tight regulations placed on manufacturers, beginning in the 1970s with the passing of the federal Clean Air Act. Between 1980 and 2010, average U.S. urban CO concentrations fell 82 percent, and levels now lie well below the National Ambient Air Quality Standards (NAAQS).

Carbon monoxide is considered a "primary" pollutant—one that may cause direct health impacts from prolonged or high-concentration exposure. The World Health Organization (WHO) suggests that only high concentrations of CO are likely to affect human health, when hypoxia (a fatal lack of oxygen) begins to take effect. WHO suggests limiting exposure to no more than 90 parts per million (ppm) molecules of air for 15 minutes, 50 ppm for 30 minutes, 25 ppm for one hour, or 10 ppm for eight hours. In the United States, the Occupational Safety and Health Administration (OSHA) prohibits its exposure to concentrations greater than an average of 50 ppm during an 8-hour time workday.

In ambient (outside) air, the NAAQS specify that CO concentrations, averaged over an eight-hour period, must not exceed 9 ppm, or 35 ppm for any one-hour average. If a region surpasses either of these standards more than once (for each measure), it is considered out of compliance and must take action to reduce its CO emissions. These standards for carbon monoxide were first established in 1971 to protect both public health and welfare, but a 1985 review determined that public welfare (that is, adverse effects to ecosystems and the natural environment) impacts of CO were insignificant at existing ambient-air levels, so these were dropped from the standards. The EPA reviewed these standards once again in 1994 and made no changes. As of 2013, these standards remain in place and measurements of ambient air at all U.S. locations are in compliance.

As a means of meeting NAAQS, the EPA sets threshold emissions rates for CO and other

pollutants from individual vehicles, a key source of urban air pollution. The latest EPA standards (as of 2013) for all light- and medium-duty passenger vehicles require emissions no higher than 3.4 grams per mile (g/mi), for vehicles at or below 50,000 miles of total use. Vehicles between 50,000 and 120,000 miles of use are allowed CO emissions rates up to 4.2 g/mi. European Union standards for carbon monoxide emissions are now stricter than those in the United States. The latest EU standards (Euro 5) allow no more than 1 gram per kilometer (g/km) (1.6 g/mi) for gasoline passenger vehicles and no more than 0.5 g/km (0.8 g/mi) for similar diesel vehicles. The next Euro regulation phase, Euro 6, will maintain these CO standards.

Localized Concentrations

Although ambient carbon monoxide emissions and levels are no longer a key concern in the United States, localized CO emissions remain a potential hazard. Certain microenvironments (like parking garages, at gas stations, and inside queued vehicles) regularly experience higher CO concentrations, and some poorly ventilated and partially enclosed areas (like underground or multistory parking structures) may trap CO, creating pockets of very high concentrations, particularly in very cold climates, during cold starts (when fuel ratios are purposefully rich).

CO levels as high as 100 ppm have been recorded for extended periods in some urban garages and parking complexes, which becomes very hazardous, even when experienced for a matter of only minutes. Running an internal combustion engine in an enclosed space (for example, a vehicle idling in a garage) can cause suddenly harmful and even fatal spikes in carbon monoxide concentration. The Centers for Disease Control and Prevention (CDC) found that it took only seven minutes for a small 5-horsepower gasoline engine in a 10,000 cu. ft room to raise ambient CO concentrations to as high as 1,200 ppm.

Smog

While ambient concentrations of CO tend to pose threats only to human (and animal) health, the gas can combine with other pollutants to form ground-level ozone, or “smog,” harming health and the environment. Carbon monoxide combines with hydroxyl radicals to produce nitrogen

dioxide from a series of intermediate reactions. Nitrogen dioxide produces ground-level ozone (smog) through interactions with solar radiation. Smog can cause eye, nose, and throat irritations in the short term and damage lung tissue, leading to chronic lung disease in the long term. Smog also reduces visibility and can damage agricultural crops and man-made surfaces.

As of 2013, many U.S. regions exceeded the NAAQS eight-hour average concentration limits for ground-level ozone (0.075 ppm). Though carbon monoxide is not the primary contributor to ozone formation, it can provide an additional catalyst for smog formation, which remains a significant concern in the United States and around the world. For example, Mexico City regularly experiences very high levels of ground-level ozone, spurred partially by high CO concentrations, and China’s urbanization has created dramatic smog episodes, readily apparent through reduced visibility.

Conclusion

As demonstrated by regulations and vehicle design trends in the United States and Europe, the public health impact of CO emissions can be greatly reduced through emissions regulations and more efficient vehicles. However, even with today’s most advanced engines, carbon monoxide emissions are inherent to gasoline- and diesel-fueled vehicles. Electric-drive vehicles provide an option to reducing CO tailpipe emissions completely, but one must ensure upstream CO emissions from power plants remain low.

Carbon monoxide emissions from automobiles have largely disappeared as a direct health threat in most ambient-air settings, but urban growth, rising motorization, and certain microenvironments can contribute to dangerous concentrations of CO, along with other harmful pollutants. Carbon monoxide emissions now represent a mostly dormant threat to ambient air quality but may cause isolated and local health episodes and should continue being monitored to ensure clean air remains the norm.

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See Also: Air Pollution/Air Quality; Automobile Emissions Controls; Automobile Emissions Inspections;

Carbon Dioxide Emissions; Clean Air Act and Amendments; Environmental Impacts; Environmental Protection Agency; Gasoline, Reformulated; Green Fuels; National Ambient Air Quality Standards; Nitrogen Oxides; Smog; Vehicle Fleet Emissions; Zero-Emissions Vehicles.

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Carpool Programs, Ridesharing and

Ridesharing has long been viewed as an approach to address problems of traffic congestion, carbon emissions, and fossil fuel dependence. The objective of ridesharing is to fill empty vehicle seats by matching riders with drivers going in a similar direction, employing vehicle occupancy potential to reduce the number of vehicles on the roadways. Ridesharing is largely realized through carpooling and vanpooling, the grouping of travelers in a private automobile or van, respectively. Ridesharing also includes more unique forms, such as casual carpooling (also known as "slugging"). North American ridesharing has a 70-year history, which began with carpooling programs during World War II and has evolved through five phases until today. Ridesharing's modal share has declined since the 1970s, when 20.4 percent of American workers commuted to work by carpool. Despite this drop, it remains the second-largest travel mode in the United States, at 10.2 percent as of 2011.

In traditional definitions, ridesharing differs from for-profit commercial transportation (for example, taxicabs, limousines) in its financial motivation. When a ridesharing payment is collected, it partially covers the driver's cost; it is not intended to result in a financial gain. Moreover, the driver has a common origin and/or destination with the passengers.

Because ridesharing reduces the number of automobiles needed by travelers, it claims numerous societal benefits, including reduced emissions, traffic congestion, and parking infrastructure demand. However, the magnitude of such benefits is unclear. On an individual level, the benefits are more tangible. Carpool and vanpool participants experience cost savings due to shared travel costs, travel-time savings through the use of high occupancy vehicle (HOV) lanes, and reduced commute stress, particularly for those with longer commute distances. In addition, they often have access to preferential parking and additional incentives.

Despite its many benefits, there are numerous behavioral barriers to increased ridesharing use. Individuals often see the attractiveness of carpooling but are disinclined to sacrifice the flexibility and convenience of the private automobile. Moreover, psychological factors, such as the desire for personal

space and time and an aversion to social situations, can impact ridesharing adoption. Personal security is also a concern when sharing a ride with strangers, although this is a perceived risk. Carpool programs over the years have attempted to address these barriers using incentives and emerging technology.

History

Ridesharing's evolution has a 70-year history in North America and can be categorized into five key phases: (1) World War II car-sharing clubs (1942–45), (2) major responses to energy crises (late 1960s–80), (3) early organized ridesharing schemes (1980–97), (4) reliable ridesharing systems (1999–2004), and (5) technology-enabled ridematching (2004–present).

Ridesharing began as a policy mechanism during World War II, encouraged by the U.S. federal government as a way to reduce the consumption of steel, rubber, and petroleum needed for the war effort. A 1942 U.S. government regulation required that ridesharing arrangements to workplaces be made when no other alternative transportation means were available. The U.S. Office of Civilian Defense created a ridesharing program called the Car Sharing Club Exchange and Self-Dispatching System, which matched riders and drivers through a bulletin board at work.

Following the war, the need for ridesharing became less apparent. However, it reemerged in the late 1960s and early 1970s at major employment sites. Large-scale employers, challenged with managing congestion and office parking supply, turned to commuter ridematching programs. These programs were simple and successful—each company collected employee data, hand-matched those who were neighbors, and distributed personalized matches. The 1973 Arab oil embargo shifted ridesharing's focus from constrained parking supply concerns to energy conservation. Employer-sponsored commuter ridematching programs caught the attention of U.S. federal agencies as an aggressive tool to achieve energy conservation goals. The Federal Highway Administration (FHWA) began cataloging successful employer ridematching programs to publish guidebooks on carpooling and vanpooling. Additionally, the 1974 Emergency Highway Energy Conservation Act provided federal highway funds for over 100 carpool demonstration programs across the United States through 1977.

As a result, carpool and vanpool programs have become a common transportation demand management (TDM) strategy, encouraged simultaneously by public agencies and major trip generators (for example, employers, universities) to reduce congestion and parking demand. Since the 1970s, other policy mechanisms, including HOV lanes, preferential parking for carpools and vanpools, and park-and-ride facilities have been developed to encourage ridesharing.

As energy conservation efforts waned in the 1980s and 1990s, TDM policies shifted focus to alleviating suburban office park congestion and air quality issues. Public agencies implemented mandatory employer-based trip reduction (EBTR) programs; the largest, known as Regulation XV, affected over 2.3 million employees in southern California. By the early 1990s, however, unrealized goals and growing opposition ended most EBTR programs. Advances in computerized ridematching during this period also marked a move toward more dynamic ridesharing applications in the form of telephone- and Internet-based ridematching programs. Notable pilot programs include Bellevue Smart Traveler, Los Angeles Smart Traveler, and Rideshare Express in Sacramento. These programs were deemed unsuccessful due to low use. Ridesharing's growth was limited during this phase due to lower gasoline prices coupled with ridesharing's lack of flexibility, safety concerns, and ride-matching challenges.

With most dynamic ridematching applications of the 1980s and 1990s failing to overcome the “critical mass” barrier (that is, providing enough users to consistently create a successful instant ridematch), most North American carpooling programs between 1999 and 2004 focused on systems to encourage ridesharing among commuters who had the most reliable trip schedules. Since 1999, private software companies began developing ridematching “platforms,” providing their suite of services to clients for a monthly fee. Carpools formed through online ridematching tended to be more static and inflexible and required prearrangement. Though it was easier to find ridematches in a larger online database, these carpools still suffered from the same drawbacks as traditional carpools, namely, regular commuters lost the flexibility that private auto travel offered. As housing and employment centers became more dispersed, offering less

incentive to rideshare, online ridematching had difficulty attracting more users than the employer-sponsored commuter ridematching programs of the late 1960s. Thus, online ridematching programs seemed to be best suited for commuters with similar, consistent schedules.

From 2004 to the present, a new generation of ridematching platforms has been developed for regions and employers to use with significant growth and overall success. Partnerships between ridematching software companies and their large-scale clients take advantage of existing common destinations and a large number of potential members. These firms sell their ridematching software “platforms” to public agencies and employers, which are sometimes used as stand-alone Web sites for each group. While this partnership strategy has gained more users than previous ridesharing phases, it is still most suited for commuters with regular schedules. Today, there are over 600 ridematching programs in North America, most of which use online, automated ridematching.

Many public agencies and employers also manage carpooling programs that provide members with incentives for “green trips.” Members are rewarded with points when they carpool, vanpool, take public transit, bike, walk, or telecommute for both work and personal trips. These points can be used for restaurant coupons, shopping discounts, and attraction tickets from sponsoring businesses.

Another major development in this phase has been real-time ridematching, made possible through social networking services (for example, Facebook) and mobile/smartphone technology. Real-time ridematching services match drivers and passengers through a smartphone “app” minutes before the trip is to take place, addressing the inflexibility of prearranged carpooling. A driver has the app open on a GPS-enabled smartphone. Meanwhile, a potential rider requests a ride through the app and is shown nearby drivers going a similar direction. Once the rider requests the ride, the driver is notified, confirms the ridematch, and drives to pick up the rider. Trips made are typically short, intracity trips. The rider pays a suggested donation, automatically calculated through the app, by authorizing a credit card transaction through the ridematching service. The app companies take a commission of that monetary transaction. After the trip, both the driver and rider rate their experience with the other party.

The rise of mobile technology and social networking to enable real-time ridematching has blurred the distinction between traditional ridesharing and commercial transportation (for example, taxis). Because of this, there remains controversy between new real-time ridematching companies and the commercial transportation industry regarding regulation, competition, innovation, and public safety. Nevertheless, real-time ridematching companies continue to expand to major cities across the United States, including San Francisco, Los Angeles, Seattle, Chicago, and Washington, D.C.

Ridesharing’s Future

Evolving technology has played a part in carpooling programs through each phase of ridesharing and will play a critical role in ridesharing’s future. Perhaps its greatest contribution will be to help overcome the critical mass barrier, which has limited the potential of this mode in the past. Interoperability among numerous ridematching databases, or a “ridematch aggregator,” could achieve a notable step in this direction.

Another area that could foster growth is multimodal integration—the seamless connection of ridesharing with other transportation modes, such as public transit and car sharing (or short-term auto access). A significant challenge to future integration and interoperability, however, is the establishment of institutions to facilitate collaboration among public agencies and private companies to support this.

Finally, supportive policies in the United States and Canada are essential to facilitating ridesharing growth over the next decade. A range of TDM policy strategies could integrate and promote ridesharing, such as free or reduced-price access to high occupancy toll (HOT) lanes, parking cash-out (that is, employees can opt out of a parking space and receive compensation from their employer who leases/owns the space), and pretax commuter incentives (that is, commuters are not taxed on ridesharing expenses). Ultimately, effective policies must demonstrate to employers and travelers that ridesharing and carpooling programs will positively impact their lives through tangible incentives.

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See Also: Car Sharing; Carpooling; Carpooling, Casual; High Occupancy Vehicle Lanes; Shared Taxis; Traffic Demand Management.

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Carpooling

Carpooling occurs when two or more people occupy the same vehicle and travel between the same or similar origins and destinations. Carpools may consist of people of the same household (called intrahousehold carpools or fampools) or may consist of friends, coworkers, neighbors, or others who reside outside the household (interhousehold carpools). Carpool arrangements may occur relative to a specific trip and remain more informal in nature or individuals may make formal arrangements (including financial) to share rides on a regular basis. Much of the research on carpool behavior has focused on formal carpool arrangements for the work commute, although newer research has extended the focus to fampools and to understanding the characteristics of carpool trips for other purposes.

Although carpooling was encouraged by governments to conserve gasoline and rubber for military use during World War II, little is known about carpooling prior to the late 1970s, when carpooling was included as a separate mode choice option in the 1977 Nationwide Personal Transportation Survey. The oil crises of 1973 and 1977 brought about an interest in finding ways to decrease American and European dependence upon foreign oil. Since transportation accounts for the largest proportion of oil use, one of the best ways to decrease dependence was to find ways to reduce transportation fuel use. In addition, increased fuel costs led to growth in carpool use from the mid-1970s through the mid-1980s. This interest in learning new ways to lessen gasoline use led to the first waves of research on carpooling behaviors in the late 1970s and 1980s. This early research focused on the attitudes and preferences for different work commute modes and ways in which public and private policies could influence changes in transportation mode choice from single occupancy vehicles (SOV) to public transportation or carpooling.

The nascent carpool research used statistical models similar to those used for analyses of consumer behavior. Thus, economic models estimating elasticity of demand for carpooling (usually measured relative to the cost of gasoline) or psychological-related models measuring individual preferences for transportation mode choices and various incentives for switching to carpooling were used. This early research was used to measure the effectiveness of various public transportation management programs, such as developing high occupancy vehicle (HOV) lanes, monetary incentives, and workplace ridesharing programs. Shares of workers carpooling declined during the 1980s despite these efforts and subsequently research about carpooling waned.

Socioeconomic and Other Differences

While early research on carpool behavior sought to understand how individuals choose carpool or public transportation over other modes, changes in the racial/ethnic characteristics of the population has expanded the research focus to seek a better understanding about who commutes and why. For instance, Hispanics are more likely to carpool than any other racial/ethnic group. The reasons for higher carpool shares for Hispanics are varied.



A high occupancy vehicle (HOV) lane for “carpools only” on a highway between Los Angeles and San Diego, California, in 2009. In the 1970s, 20.4 percent of American workers commuted by carpool. By 2011, that number had fallen to 10.2 percent.

Hispanic workers may have higher commuting cost burdens (as a result of lower earnings relative to the costs of fuel, maintenance, parking, and distance traveled). In addition, Hispanics have larger average household sizes than other racial/ethnic groups, and as a result, Hispanic carpool arrangements are more likely to consist of family members than any other group. Finally, lower licensure rates of Hispanics, and particularly Hispanic women, leads to the formation of carpools where public transportation is not available or where it may be difficult to access and use.

Of special interest to researchers are the ways in which immigrants use carpools for work or other trips and how the use of carpool arrangements among immigrants changes with time in the United States. Carpooling may be thought of as a form of social capital—a way for new immigrants to use the assistance of others to navigate new environs. Language, cultural, educational, and legal barriers may keep immigrants from driving on their own so they must depend on other

arrangements, such as carpools, to get to work or other activities. With time in the United States, these immigrants may become more like the native born and carpool less. While some of these immigrant carpool arrangements are the same as carpool arrangements of nonimmigrants, that is, informal arrangements between family, friends, neighbors, or coworkers, researchers have discovered through qualitative research ways in which some immigrant carpool arrangements may look more like taxi services. In these instances, other immigrants operate often unlicensed vans or small buses, charging flat fees to transport fellow immigrants to work or other places.

Alternative Carpool Arrangements

Increases in gas costs in the first decade of the 21st century and continued interest in environmental issues led to renewed interest in research on alternative forms of transportation. In many ways, this new research has returned to the same issues of the 1970s and early 1980s, trying to understand and evaluate the effectiveness of public policies designed to incentivize carpooling or create disincentives to driving alone.

This research has also expanded into uncovering the ways in which people arrange carpools. For instance, one phenomenon studied has been the development of a system whereby individuals wait near an entrance to a high occupancy vehicle (HOV) lane to be picked up by drivers wishing to avoid congestion in non-HOV lanes. These informal carpool arrangements are called slugging. New research has also investigated the effectiveness of dynamic ridesharing programs that use the Internet and smartphones to arrange regular or occasional carpools via online carpool arrangement services.

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See Also: Automobile Culture; Carpool Programs, Ride Sharing and; Carpooling, Casual; Mode Choice Models; Traffic Congestion.

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Carpooling, Casual

In traditional carpooling, employees from the same company or individuals who work in close proximity prearrange travel together to work to save money and possibly take advantage of benefits such as carpool parking or the use of high occupancy vehicle (HOV) lanes to save time. However, carpooling is infrequent, with rates in the United States at just over 10 percent according to the U.S. Census Bureau's 2005–07 American Community Survey. Many who have the opportunity to carpool but choose not to cite the inflexibility and inconvenience in being tied to another person's schedule or that they themselves do not have regular work schedules.

Casual carpooling, colloquially dubbed "slugging," brings anonymous strangers together on the fly to travel together to save time and money. In this system, lines of riders congregate at designated locations. Drivers pull alongside the line and shout their destination or have a sign affixed to their vehicle. The first two commuters in the queue also traveling to that location enter the car

and, with three passengers, the vehicle can enter the HOV lanes, which can reduce the commute time by 30 percent. While some metropolitan regions across the world have fledgling casual carpooling cultures, slugging is well developed in the Washington, D.C., metro area, the San Francisco Bay region, and Houston, Texas.

Origin

Slugging originated in the Washington, D.C., metro area during the mid-1970s. At that time, commuters were concerned about gas prices and availability due to OPEC (Organization of the Petroleum Exporting Countries) oil embargoes. Concurrently, Northern Virginia's I-95/I-395 (Shirley Highway) opened the first freeway HOV lane, requiring at least three passengers to gain admittance to this coveted stretch of roadway operating between Prince William County in Virginia and Arlington Street near the Pentagon. Motorists who wanted to take advantage of the quicker HOV lane would drive up to bus lanes and solicit riders. Bus drivers, who were trained to spot "slugs," or counterfeit coins, it is said, began calling the commuters waiting in the bus line slugs since they were using the bus stops not for public transit but for a ride in a private vehicle.

Rules of Etiquette

While each slugging region has particular norms, over the past three and a half decades of casual carpooling, clear rules of etiquette have emerged for participants. Drivers are expected to drive safely and responsibly, have working seat belts, and present relatively clean vehicles. For their part, passengers are expected to refrain from eating and using their cell phones. They are typically quiet unless talked to by the driver. Reporters and researchers who have participated in casual carpooling note that some rides are silent, but others turn into enjoyable roundtables with lengthy discussions, and one man indicated he and his wife had met through slugging. The drivers can have quiet music or radio talk stations playing, as long as they are not overtly religious or political, and the passenger does not ask the driver to change the music or station, nor does the passenger make requests to alter the climate control settings. Historically, no money has changed hands between driver and passenger. In 2010, however, the Bay Area Toll Authority began charging cars in the carpool lanes a minimal fee,

currently at \$2.50, to cross bridges in the San Francisco area. The necessity to discuss financial transactions in the casual carpooling community ignited a firestorm of debate, with some passengers adamantly against contributing to the toll, some willing to pay whatever the driver requested, and some always contributing a dollar.

Since the toll's introduction, a consensus has emerged that passengers pay \$1 toward the toll, though the fiery debate reveals the dynamic social contract underlying casual carpooling. However, without these social norms, passengers would likely not feel comfortable entering a stranger's car for a lengthy commute. The rules of etiquette provide a shared sense of expectations that undergird a thriving slugging community.

Structural Requirements

Clear and widely accepted rules of etiquette provide the social context needed for casual carpooling. However, successful casual carpooling areas also share certain structural requirements. Researchers conducting the Casual Carpooling Scan report observed that slugging flourishes in areas with barrier-separated and reversible HOV lanes. Typically, HOV-3 lanes, those that require at least three passengers, see more slugging than regions with HOV-2 lanes. Park and ride lots, particularly ones that provide direct access to HOV lanes, spur slugging as well. The researchers also observed that the slugging communities typically have high travel demand, at both the origin point and the destination. At the destination, typically parking is rare or, when available, prohibitively expensive. In the cases of Washington, D.C., and San Francisco, a high proportion of workers travel to a tight geographical area. Additionally, passengers prefer a public transportation backup in case they are unable to secure a ride in a private vehicle. Most slugs want to be able to see bus lines from the slug lines so that they can make a choice to use public transit or wait for the next privately owned car.

Usage

The number of participants taking advantage of casual carpooling can be difficult to measure, although a handful of studies have been conducted on this carpooling subculture. The most prevalent research techniques involve participant-observation studies, interviews, and surveys. In May 2011,

511 Rideshare conducted observation studies and distributed surveys in the Bay Area at 13 East Bay slugging lines and one line in San Francisco. Based on their observations and the results of the survey, 511 Rideshare estimated a weekday daily participant rate of 6,100, a decrease of 9 percent since 2010. Survey respondents said they used casual carpooling to save time and money. Those who did not frequently use casual carpooling explained that they found it too onerous and confusing or that they did not have public transportation options for their commute home. Others cited the awkwardness or confusion brought on by the injection of money in the system when the Bay Bridge Toll Authority required the new toll on vehicles traveling in car-pool lanes.

The Washington, D.C., area claims about 10,000 participants in casual carpooling each weekday, perhaps because of the availability of information or because most slugs work for the federal government and have similar and consistent work schedules. Under the direction of Mark Ojah and Mark Burris, researchers observed casual carpoolers at select slug lines in June 2003 to estimate participation rates. Their observations indicated approximately 500 participants per day at the three slugging sites surveyed.

Since their research, one of the highways with slug lines was renovated. In addition to adding lanes to the highway, the HOV lanes were transformed into high occupancy transit (HOT) lanes, which allow single occupancy vehicles to use the lanes for a toll. Since the renovations, the number of casual carpoolers in the Houston area has decreased substantially. Among slugs, the Scan researchers noted diversity in terms of gender, ethnicity, socioeconomic status, and employment class.

Environmental Benefits

Most casual carpoolers join the ranks of slugging not because of the environmental benefits but because of the time and financial savings that comes from ridesharing. However, the practice does have environmental benefits. According to the Environmental Protection Agency, 27 percent of U.S. greenhouse gas emissions can be attributed to transportation. Passenger vehicles compose almost 60 percent of the sources of greenhouse gases. Automobiles and highway vehicles utilized roughly half of all the petroleum-based energy

used in transportation. At the same time, 75 percent of highway seats are empty, according to Raj Kapoor of the Mayfield Fund. When those empty seats are filled, fewer private vehicles are on the highway system, which amounts to 6 million fewer gallons of gasoline used annually, thereby reducing greenhouse gas emissions from commuting. Additionally, fewer private vehicles translate into a reduced amount of land exploited for roads and parking spaces.

Paul Minett and John Pearce used modeling techniques to calculate that bus and single occupancy vehicles use 24 percent more energy than casual carpooling based on participation and ridership in the Bay Area, amounting to annual cost savings of \$30 million.

Safety

Though slugging benefits the environment and saves time and money, safety can be a concern when accepting or giving rides to strangers. As noted, casual carpooling succeeds when the HOV lanes require three-person occupancy. In areas with HOV-2 lanes, or a minimum requirement of two persons in each vehicle, casual carpooling has not been as popular. Many observers attribute this to the perceived safety of being with two other people instead of just one. However, when sluggers discuss safety, they more often refer to concerns regarding safe driving.

Drivers who consistently drive recklessly or unsafely are soon called out on the local casual carpooling Web sites (www.Slug-Lines.com in Washington, D.C.; www.ridenow.org in the Bay Area). Erratic, aggressive, or even strange-acting passengers are also described on the message boards. People in the slug lines can wave off or pass a ride offer without negative consequences if they feel unsafe or uncomfortable entering a particular vehicle. The Scan researchers speculated that safety issues were minimized in the Washington, D.C., area since most of the slugs are government employees with similar dress codes and often wearing federal ID badges.

Role of Transportation Officials

Most regional and local transportation officials have little involvement with the existing self-managed slugging communities. Some, however, actively discourage slugging because they believe that the practice negatively influences public

transportation usage and revenue. In the Bay Area, the Bay Area Rapid Transit (BART), concerned about this issue, takes steps to ensure that casual carpoolers do not use the parking lots reserved for public transit customers. They have designed some park and ride lots so that to pay for the parking, users must first pay for a BART ticket, thereby eliminating any financial benefits to slugging and reserving the park and ride lots for paying customers. At the same time, the Metropolitan Transportation Commission (MTC) provides a link to the local slugging Web site, and in 2007, Randy Rentschler, then director of legislation and public affairs at MTC, asserted that carpooling composes the largest category of vehicles that pass over the Bay Bridge during morning traffic and was a positive practice that benefited all community members.

In northern Virginia and Washington, D.C., public transit does not have the capacity to meet the needs of all commuters, and local governments have supported the efforts to promote casual carpooling. The Potomac and Rappahannock Transportation Commission (PRTC) actively encourages casual carpooling by disseminating information and advising on regard to location placement for slugging queues. Additionally, the Arlington County Commuter Service has provided an annual grant to David LeBlanc, operator of the Web site www.Slug-Lines.com. Researchers in Atlanta, Georgia, and San Diego, California, have conducted studies to explore the possibility of casual or dynamic carpooling to reduce the burden on their congested traffic system. With increasing cuts to public transportation budgets nationwide, casual carpooling and other types of ridesharing might fulfill an important need as capacity is cut.

Advent of Dynamic Carpooling

Casual carpooling is inherently limited by the infrastructure that supports its development. Some consumers might be willing to share rides in areas without the structural characteristics that give rise to slugging. Advances in technology, particularly the high usage of smart phones, allow individuals to quickly arrange rides on short notice. Unlike traditional casual carpooling, participants make plans with particular and known drivers and passengers. Zimride, founded by John Zimmer, which has facilitated long-distance ridesharing, has received \$6 million from Mayfield

Fund to allow drivers to “sell” empty seats in their cars. Riders pay a fee through the Zimride service, and the driver is compensated minus transaction fees. An advantage of this system is that participants are not limited by set pickup/dropoff locations. To allay safety concerns, users of the system must verify they are associated with participating corporations or universities. They must also link their Facebook account. Either drivers or passengers can pass up the match based on the information contained in the user’s account.

Paul Minett, chief executive officer of Trip Convergence based in New Zealand, is also trying to facilitate dynamic ridesharing both in his home country and within the United States. Though the technology-based services provide more flexibility to individuals who would like to share rides, they introduce a commercial element that has been absent from the slugging culture.

Promoting casual or dynamic carpooling can reduce the use of natural resources, diminish harm to the environment, and decrease stress on overburdened transportation systems. New technologies might be able to encourage skeptical individuals to join the slugging ranks.

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See Also: Carpool Programs, Ride-Sharing and; Carpooling; Commuting; High Occupancy Toll Lanes; High Occupancy Vehicle Lanes.

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Chicago Area Transportation Study

The Chicago Area Transportation Study (CATS) was an organization that played a major role in developing regional transportation modeling and significantly shaped the way transportation planning is done in the United States today. Although the first metropolitan-level transportation study was carried out in Detroit in 1953, CATS researched and standardized the process starting in 1955. This work led to the institution of the Metropolitan Planning Organizations that exist in all major US metropolitan areas, as well as the Urban Transportation Modeling System (UTMS) that is key to transportation planning and engineering.

At the time of CATS’ founding, there were already nearly 300 miles of limited access roads built or approved in the Chicago area, but the question remained of how the system would be updated as the region continued to grow. A three-volume study of travel surveys, land use and travel forecasts, and plans for dealing with future growth

was proposed to be carried out within the developed parts of the region. At that time, this included the city of Chicago, the remainder of Cook County, all of DuPage County, and the innermost fringes of Lake and Will Counties. Local, state, and federal funding contributed to the establishment of CATS as an independent organization, and its board included no elected officials in an attempt to remain politically neutral.

At the start of the process, members of CATS and relevant jurisdictions realized that some of the data they were using had not been updated since the 1930s, so not only would they need to carry out intensive data collection, they also would need to develop an institution that would ensure those data were updated regularly.

However, the data collection soon proved too intense to be easily repeatable. Interviews were conducted with 57,000 households across the region, about 1 in 30 of those in the metropolitan area. Cordon interviews gathered data from 200,000 travelers in trucks and cars at multiple entry points into the Chicago metropolitan area. Surveys were conducted with 9,000 rail commuters with the assistance of the then privately owned railroads, and a survey of boat captains on the Sanitary and Ship Canal was done as well.

Finally, CATS carried out a never-before-done land use survey of the metropolitan region. Over 300 temporary employees carried out the various surveys at a cost of a million dollars in 1956, and the study itself was not completed until 1962. Ironically, despite the beginning goals, the intensive nature of data collection has made it a feat that has never been replicated.

Outcomes

Nevertheless, the survey and its subsequent analysis did have other long-lasting effects. CATS pioneered a 10-step process of what has since come to be known as the rational planning model: data collection, data analysis, forecasting, establishing goals, designing alternatives, testing alternatives, evaluating alternatives, selecting an alternative, implementing the alternative, and monitoring the alternative. This rational planning model is still the foundation for most American transportation planning. Staff in CATS had backgrounds in planning, sociology, economics, mathematics, journalism, geography, and engineering, leading to an unusually

multidisciplinary approach that strengthened the development of the planning model.

There were tangible outcomes as well. Within Chicago, notable impacts of the three-part study include the implementation of three recommended rail lines in the 1960s and 1970s: the Skokie Swift, the Red Line in the median of the Dan Ryan Expressway, and the Blue Line in the median of the Kennedy Expressway. At the same time, none of the recommended expressway additions were made, including the Crosstown Expressway that would have run north-south east of Cicero Avenue from the junction of I-90 and I-94, past Midway Airport, and then east near 75th Street.

The project was successfully fought in the 1970s by community groups who had already seen thousands of housing units lost to regional expressways. The shift from expressway projects to transit at this time was hardly unique to Chicago, demonstrating that even the rational planning model had its limits in terms of translation from computers and maps to concrete and pavement.

Urban Transportation Planning

At the same time that CATS was developing what is known today as urban transportation planning, the federal government was moving toward the same regional approach to managing population and traffic growth. The 1962 Federal Aid Highway Act included the proviso that metropolitan areas with populations over 50,000 would not receive federal highway aid unless there was a continuing, comprehensive, and coordinated planning process in place. By 1965, this requirement had expanded, and projects proposed by a local government that could receive federal funding had to be approved by a regional agency to ensure they fit into the regional plan. Since CATS already existed, it slid into this role.

In 1973, Congress established and funded Metropolitan Planning Organizations (MPOs) to fill this role in a more standardized fashion across the country and to provide regional organizations with more authority over state and local governments by requiring MPO approval for the disbursement of federal transportation funds, as well as a 3–5 year plan that included both highway and transit projects. Again, CATS was designated as the official MPO for the six-county region, now with one elected official from the Council of Mayors on its board.

Agencies

The Chicago region is well known for its intensive fragmentation of local governments, and regional transportation planning is no different. As CATS was working on its initial study in 1957, the Illinois General Assembly was creating another agency, the Northeast Illinois Planning Commission (NIPC), to study regional planning and assist local governments. If CATS was founded to understand the transportation and land use patterns of the Chicago region and predict and provide for their future needs, NIPC was founded to deal with the extreme fragmentation of local government that made transportation and land use such difficult issues. As an advisory body, NIPC did not have the stick of federal transportation funding access to wave at local governments, but rather it provided the carrot of cooperation in local planning concerning water, open space, and stormwater. Larger than CATS, NIPC covered a six-county region (Cook, DuPage, Kane, Lake, McHenry, and Will).

As time went on, NIPC took on the role of forecasting population and traffic via funding from the National Housing Act, while CATS carried out the MPO functions of disbursing federal transportation funds. The two agencies collaborated closely and were even located across the street from each other in Chicago's Loop. By 1994, the agencies worked together directly to produce a single regional transportation plan, projecting out to 2020. This planning process led to discussions of merging the two agencies to better integrate transportation and land use planning within the region. In 2005, the state legislature passed the law that merged the two into the Chicago Metropolitan Agency for Planning (CMAP), despite concerns from some local governments that Chicago would gain too much power in the process, as representatives were to be apportioned by population.

Unlike CATS, the CMAP board members are appointed by elected officials, one-third each from Chicago, Cook County, and the six remaining counties of the metropolitan area taken together. Currently, CMAP has 102 employees and a budget of \$15.7 million. The original proposal would have also brought into CMAP the Regional Transportation Authority (RTA), the agency that oversees bus and rail transit in the region, in order to integrate public transportation with traditional land use and transportation planning. Although that effort

failed, there has been renewed interest in the early 2010s in incorporating the RTA.

Effects

One of the most lingering effects of CATS has been the development of the travel demand forecasting model: trip generation by zone, modal split, trip distribution among zones, and traffic assignment. The Bureau of Public Roads, which later became the Federal Highway Administration (FHWA), expanded upon CATS's work to produce the familiar Urban Transportation Modeling System, or UTMS. Another significant contribution was to link land use forecasting to transportation planning, although the chicken-and-egg question of which should be taken first in modeling the other remains to be solved.

At the same time, a significant criticism of CATS is that the quantitative emphasis of the study's work claimed to be value neutral. However, the practice of extrapolating current trends and providing sufficient infrastructure to meet those trends did not consider if the current transportation and land use needs of those outside the middle-class, white, able-bodied population were being met. The assumption of the individual, rational actor led to mapping "desire lines" that demonstrated current travel patterns while assuming those were the optimal patterns to be achieved in the future. This "predict and provide" model has been critiqued as claiming to be value neutral when it actually is not. In contrast, a "predict and decide" model would offer possible scenarios for dealing with future populations and employment growth rather than simply expanding existing infrastructure.

The individual, rational actor was also a problematic assumption, considering the racial segregation written into housing covenants in much of the region, the large-scale federal subsidization of suburban expansion via Veterans Administration and Federal Housing Administration loans, and the gender segregation that existed at the time in terms of daily travel behavior. Nevertheless, the legacy of CATS in terms of linking land use and transportation, as well as taking a multidisciplinary and multi-jurisdictional approach to transportation planning, changed the way that metropolitan areas developed across the country and beyond.

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See Also: Metropolitan Planning Organizations; Network Modeling; Regional Transportation Planning Organizations; Regional Transportation Plans; 3C Planning Process; Transportation Planning; Travel Demand Forecasting; Travel Modeling; Urban Transportation Modeling System.

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educational, and leisure destinations. Transportation policies can also generate equity problems because poorer persons can't use existing networks to get to these and jobs or exploit other resources. At different times, social movements have arisen to challenge established patterns of accessibility to transit, in terms of the rights of passengers and the extent to which existing transit services meet given transit dependents' needs. A particular focus is on how African Americans and other disenfranchised minority groups can gain political power over decisions in the mass transportation system.

One starting point is the historical legacy of racial discrimination and unequal access to power in U.S. history. The Civil War ended in 1865, but despite passage of the Fourteenth Amendment guaranteeing equal legal protection to all citizens, beginning in 1881 and through the 1940s, localities and states in the South adopted various laws that mandated racial segregation in public transportation and eventually virtually all aspects of life. This system, codifying existing behaviors and customs, was known as Jim Crow.

The U.S. Supreme Court sanctioned the practice in the infamous 1896 *Plessy v. Ferguson* case. Mark Newman (2004) notes that "the anonymity of urban living and the racial equality implied by shared use of new forms of public transportation led whites to segregate the races by law, so that previously established but unwritten 'rules' governing behavior between the races received legal sanction." This created an eventual political base for the Civil Rights Movement and its efforts to overturn the *Plessy* decision and achieve equality in transportation and other spheres.

The Montgomery Bus Boycott and the Civil Rights Movement

An early example of direct action to promote mass transit civil rights in the South took place in June 1953. At that time, the Reverend T. J. Jemison took the lead in organizing a boycott of buses in Baton Rouge, Louisiana. The week-long boycott led bus seating to be allocated on a first-come, first-served basis. African Americans would no longer have to give up their seats to whites. In December 1955, Rosa Parks was arrested for refusing to sacrifice her seat to a white man on a crowded bus. Parks was a member of the Montgomery National Association for the Advancement of Colored People (NAACP) and

Civil Rights and Transportation

Transportation has become a civil rights issue because there can be an uneven distribution of access to public transportation services by minority residents needing to reach shopping, work, medical,



After attending an event in Dearborn, Michigan, on April 18, 2012, President Barack Obama took a moment to sit in the bus that Rosa Parks made famous in December 1955. Because of its importance to the Civil Rights movement, as well as to the history of transportation in the United States, the bus has been preserved at the Henry Ford Museum.

attended the Highlander Folk School (a social justice leadership training center) in 1955. Her arrest led to a boycott of the Montgomery bus system.

Edgar Daniel Nixon, who paid Parks's bond, and the Women's Political Council (WPC) developed the idea for the boycott. The WPC comprised 300 middle-class African American women. Their activities included voter registration and putting pressure both on the city of Montgomery to hire African American policemen and on merchants to desegregate the use of public drinking fountains. After Parks was arrested, Nixon brought up the idea of a boycott to prominent local African Americans. The WPC began to organize the boycott on the day of Parks's trial. Jo Ann Robinson, a professor at all-black Alabama State College and WPC president, publicized the protest by preparing and distributing 40,000 mimeographed handbills, while Nixon sought support from local black clergy. The support

of religious leaders was key because of the respect ministers enjoyed and their authority among all classes. They were also economically independent of whites. Under political pressure from activists and the growing turn of events, the majority of the city's initially reluctant African American clergy endorsed, publicized, and helped organize the boycott. Parks was convicted and fined, but over 90 percent of African American bus riders observed the boycott.

This strong community support led church and secular community leaders to create the Montgomery Improvement Association (MIA) to maintain the boycott until demands were met. These included hiring African American bus drivers for black neighborhoods; first-come, first-served seating; and more courteous treatment. On Montgomery buses, whites had claim to the first four rows of buses, with blacks limited to the rear even though

they comprised more than 75 percent of bus system riders. Blacks could take middle seats until they were needed by whites. They then had to move to seats in the back, stand, or leave the bus if there was no room.

The MIA chose Martin Luther King, Jr., as its president, and he became a central figure in the successful boycott, which lasted 381 days. The campaign ended shortly after November 13, 1956, when the U.S. Supreme Court outlawed segregation on Montgomery's buses in the case of *Browder v. Gayle*. These events not only captivated the United States but also helped transform King into a national leader.

Legislation, Regulations and Policy Proposals

The efforts of the Civil Rights movement are partially reflected in legislation governing the Department of Transportation (DOT). The DOT has a Departmental Office of Civil Rights (DOCR) which enforces regulations and laws that prohibit discrimination on the basis of age, color, disability, national origin, race, religion, and sex in both employment and the provision of government services. This office helps ensure that recipients of DOT funds carry out federally assisted activities and programs in a nondiscriminatory manner.

The civil rights–related activities that the DOT enforces through DOCR include Titles VI and VII of the 1964 Civil Rights Act as amended, the Equal Pay Act of 1963, the Age Discrimination in Employment Act of 1967, and Section 504 of the Rehabilitation Act of 1973, as amended. Title VI prohibits discrimination by those transit providers receiving federal financial assistance on the basis of color, race, and national origin, including denial of meaningful access for persons with limited proficiency in English.

The DOT can also issue administrative rules that promote civil rights and social justice objectives. For example, in November of 2013 Anthony Foxx, U.S. Secretary of Transportation, announced that his agency would require automated airport kiosks and airline Web sites to be accessible to passengers with disabilities. The DOT also issued regulations related to storage of wheelchairs on passenger aircraft. The DOT Order on Environmental Justice (DOT Order 5610.2 (a)) represents a complement to civil rights legislation by creating a process by which the DOT and the Federal Transit Administration (FTA)

integrates environmental justice goals into existing operations. This helps ensure that such goals are considered in activities, policies, and programs at various stages of planning.

Both Title VI and DOT regulations prevent federal-aid recipients from intentionally discriminating against people on the basis of color, race, and national origin. DOT rules and regulations enforcing Title VI also make clear that even policies or practices that unintentionally produce “disparate impacts” on minority populations or “disproportionate burdens” on low-income persons are prohibited.

Transit agencies monitor their performance in carrying out civil rights practices in a variety of ways. One way is to study demographic ridership and travel patterns. In some cases, fixed-route providers of public transportation that meet certain thresholds are obligated to collect information from riders on race, color, national origin, language spoken at home, English proficiency, and travel patterns of their rides by using customer surveys. Providers of transit are obligated to use such information to compare minority and nonminority riders in terms of demographics and trips taken. Moreover, demographic information about fare transit usage among low-income and minority users is collected to assist with assuring fare equity.

Transportation development and equity policies can be used as a way to promote the democratic access to resources. Fair housing advocates have supported new policies to increase development of new affordable housing and preserve affordable housing in the immediate vicinity of a newly funded transit stops. The FTA supports affordable housing and so explicitly recognizes the linkages between housing and transportation. FTA funds can influence urban development and housing patterns. Such funds can influence the extent to which open housing opportunities for protected classes are promoted (a stipulation of the Fair Housing Act) or whether barriers to fair housing are created.

The Leadership Conference on Civil and Human Rights (2011) argues that “transportation policy has the potential to expand economic opportunity for low-income Americans and underrepresented workers by connecting them to highway, transit, and rail construction jobs.” It notes that “transportation spending generates jobs for workers in the

construction industry and also has indirect effects on job creation by increasing the efficiency of the transportation system and improving business productivity.”

Transportation Equity, Economic Development and Civil Rights

When transportation developments promote gentrification and displacement of certain communities, equity problems may emerge as poorer communities may lose while wealthier income groups can gain. After World War II, highway projects cut through minority urban neighborhoods to shuttle commuters to and from suburban areas.

K. H. Shaeffer and Elliot Sclar (1980) write that “the quality of human life depends on the amount of access we have to one another.” The collocation of work and community living may create access, as can mobility but, they argue, “mobility and access are not the same.” When work and community are divided, however, access can be essential, creating problems when certain groups dependent on public transit are segregated in neighborhoods that do not have proximate access to jobs. Accessible mass transit then becomes essential for employment, economic power, and hence the political power that economic participation brings. Some communities may also be denied their fair share of public transit investments or be forced to pay more for transit services than they can afford.

Equity advocates like Wade Henderson, Leadership Conference president and chief executive officer (CEO), has argued that “millions of low-income and working-class people, people of color, and people with disabilities live in communities where quality transportation options are unaffordable, unreliable, or nonexistent.” A basic problem is that the average cost of owning a car is somewhat less than half of the federal poverty income level for a family of four. As a result, in recent years one-third of low-income African American households didn’t have automobile access, in contrast to 25 percent for low-income Latino families and 12.1 percent for white families. Budgetary policies can lead to equity problems because while the federal government has allocated about 80 percent of its transportation funding to highways, racial minorities have been four times more likely than white Americans to use public transportation to get to their jobs. Many jobs suitable for welfare-to-work

participants have not been accessible by using public transportation. A large share of the jobs in the largest metropolitan areas in the U.S. lie 10 miles or more beyond the urban core. Therefore, equitable access has been linked to increased investments in mass transit and comprehensive networks including and linking such transit to pedestrians, bicycle paths, and roads.

Bus Riders Union

Some of the contemporary challenges in transportation equity have been addressed by the Bus Riders Union (BRU). Also known as *Sindicato de Pasajeros*, the BRU began operating in 1992 as part of the Los Angeles-based Labor/Community Strategy Center’s Transportation Policy Group. This initiative began by organizing bus riders in a campaign to fight against racial discrimination, which the group argued was reflected in the policies of the Los Angeles County Metropolitan Transportation Authority (MTA).

In 1994, the BRU led protests against a large fare hike and MTA plans to develop a commuter-oriented, regional rail transit network, obtaining a temporary restraining order to stop the MTA. BRU sued the authority for violating the civil rights of bus riders dependent upon buses. That year The Labor/Community Strategy Center and BRU, together with other community and civil rights organizations, sued the MTA in 1994 in federal court for violating the civil rights of public transit riders who depend on buses, obtaining a temporary restraining order to stop the MTA’s fare increase. They charged that the authority had violated Title VI of the 1964 Civil Rights Act, the provision prohibiting government agencies, receiving federal funds from distributing them in a racially discriminatory manner. The MTA was accused of creating “a separate and unequal mass transit system—a dilapidated, overcrowded bus system for 400,000 overwhelmingly Latino, Black, and Asian/Pacific Islander bus riders.”

In 1996, the BRU and other advocacy groups filed a civil rights lawsuit that said that the MTA had not done enough to keep fares affordable or to prevent overcrowding. A settlement agreement between the parties resulted in a civil rights consent decree that mandated federal court oversight of the system for the next decade. It also required the MTA to spend \$1 billion to add new transit lines

and more buses on existing routes. The mandated oversight expired in 2006, only to be followed later by cutbacks in bus service that promoted hardship in minority communities. More recent BRU initiatives have focused on fighting fare hikes and promoting dedicated bus lanes.

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See Also: Economic Development; Employment Location; Environmental Justice; Social Equity and Discrimination in Transportation; Transportation and the Disadvantaged; Travel Patterns by Race/Ethnicity.

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Clean Air Act and Amendments

The Clean Air Act of 1970 (CAA) was the first major comprehensive, substantive engagement by the federal government with the human and environmental health effects of pollution. The act, administered by the Environmental Protection Agency (EPA), created uniform nationwide enforceable air quality standards. It designated two primary categories of polluters subject to regulation: stationary sources, (primarily industry) and transportation "mobile sources." For over four decades, the CAA has coevolved with all aspects of our transportation systems and is now embedded in decisions ranging from fuels and vehicle design, systems planning, and modal selection to infrastructure project funding, design, construction, and operation.

These transformations have been facilitated by the development of robust administrative networks involving the EPA, the U.S. Department of Transportation (USDOT), state departments of transportation and environment, metropolitan planning organizations (MPOs), and the broad spectrum of transportation industries. This robust framework plays a central role in improving sustainability in a period of continuing economic and environmental change.

Comprehensive pollution management involves a systems approach integrating sources—pathways/receivers. This is particularly challenging in a nation as large and complex as the United States with millions of vehicles, numerous unique land use and meteorological regions, and a spectrum of human health, ecological, and built environment receivers that may be impacted by airborne pollutants. The CAA requires the EPA to regulate the National Ambient Air Quality Standards (NAAQS). In 1970, scientific and technical understanding of all components of these systems and

their interactions was poor. NAAQS cover six basic airborne pollutants: carbon monoxide (CO); lead; nitrogen dioxide (NO₂), ozone (O₃); particulates; and sulfur dioxide (SO₂). Photochemical smog is an atmospheric product involving many components, including NO₂, O₃, and particulates from vehicular sources.

The CAA was revolutionary in its use of federalism to meet the newly established air standards. The EPA conducts research and establishes standards. Governors of each state designate “air quality control regions” approved by the EPA. States monitor air quality and submit annually to the EPA whether the regions were in “attainment” or “non-attainment” for each pollutant. The EPA provides technical, financial, and educational assistance to the states to ensure that the data generated is valid for regional management and that it can be aggregated for national air quality modeling, policy analysis, and program evaluation.

From 1970 to 1990, the primary transportation air pollution focus of the EPA was on national vehicle emissions reduction. The CAA’s NAAQS primary regulations are based solely on the health of receivers, such as lead exposure in children. However, the CAA states the means by which these standards are met must consider effects on the economy. The Supreme Court has interpreted the Clean Air Act as a “technology-forcing” law, meaning the EPA can set industry requirements that are technically feasible but not currently widely used. The timing of implementation of pollution-reduction mandated actions is often extended.

The EPA and DOT began voluntary measurements of fuel efficiencies for new autos, sport utility vehicles, and light trucks for each manufacturer to determine a baseline. In 1975 the EPA mandated a 100 percent improvement in Corporate Average Fuel Economy (CAFE) levels by 1985. Other CAA transportation initiatives include elimination of lead additives in fuel, development of biofuels; evaporative controls on gas tanks; catalytic converters; and standards for jet aircraft engines, diesel, and outboard engines and off-road vehicles.

Clean Air Act Amendments

A central focus of the 1990 Clean Air Act Amendments (CAAA) was urban air pollution, smog, and CO from mobile sources, which had continued to increase since 1970 despite CAFE standards, due

to growth of metropolitan populations and vehicle miles traveled (VMT). The CAAA gives the EPA increased authority and requires it to review new science and to update regulations on a five-year cycle. States must implement monitoring, planning, and enforcement programs.

A State Implementation Program (SIP), updated every three years, provides a unified framework for statewide and regional programs. Air quality in management regions that meets NAAQS is classified as “maintenance”; decreases in this air quality level are not allowed. Regions that do not meet standards are classified “nonattainment” and are rated on a hierarchical scale from “moderate” to “extreme.” The ratings determine the extent and timing of the mandated SIP programmatic actions to achieve “conformance.” The SIP includes both statewide and regional air quality conformance elements. A key SIP component for nonattainment regions is the motor vehicle emission budget (MVEB), the fraction of total regional air emissions that is allowed from mobile sources for each pollutant.

In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) declared that the nation’s integrated transportation system shall include significant improvements to achieve national goals for improved air quality. ISTEA is proactively multimodal. To implement CAAA, it broadly expands the role of metropolitan planning organizations (MPO). MPOs are assigned the responsibility to certify that both their Long Range Transportation Plan and the projects within their annual Transportation Improvement Program (TIP) are in “conformity” with the SIP’s MVEB for their air quality region. These analyses are done by integrating EPA-developed air pollution models with MPOs continuing Traffic Demand Model modeling. Outputs estimate future VMTs. While smog is a regional phenomenon related the metropolitan system, unhealthy CO levels can be highly localized. To address the latter, projects involving vehicular traffic CO “hotspots,” such as highly congested intersections, undergo specialized studies as a basis for conformity designation.

States and MPOs have numerous alternatives to achieve reductions in VMTs and emissions. Traffic control measures for existing vehicular systems, such as designated bus lanes and “smart signals,” can be used to upgrade existing facilities. New

multimodal projects, such as light rail and bicycle commuting, play an increasing role in achieving conformance. These initiatives can synergistically stimulate “smart growth” and other local and regional land use management innovations that help reduce vehicular travel demand.

Analysts agree that the CAA has been the primary driver in the continuing transformation of the nation’s transportation system toward the goal of environmentally sustainable performance. In 2011 an agreement was reached to double current CAFE fuel efficiencies by 2025. Complex transportation nodes such as major airports and international container ports that integrate shipping, rail, and truck traffic are subregional “hotspots.”

Specialized operations analyses and monitored demonstration projects are under way to develop integrated air quality management approaches for these facilities that must rapidly respond to global economic change. New CAA transportation challenges continue to emerge, such as the impact global warming will have on photochemical smog creation and the role transportation will be assigned by the government in controlling greenhouse gases.

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See Also: Air Pollution/Air Quality; Greenhouse Gases; Intermodal Surface Transportation Efficiency Act; Metropolitan Planning Organizations; National Ambient Air Quality Standards; Vehicle Emissions Standards.

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Climate Change, Transportation Adaption to

Impacts from climate change occurring now and those projected for the future pose considerable and escalating threats to transportation systems, including bridges, highways, tunnels, railways, buses, heavy and light rail vehicles, ferries, and so forth. They exact a tremendous toll on the financial and social capital resources of transportation agencies—from national and state transportation departments to metropolitan planning organizations and local public transit authorities—when they influence service disruptions, equipment failures, and infrastructure loss. As a result, the ability of transportation agencies to provide safe, reliable, and efficient travel resources and services for all segments of society for the purposes of social and economic development and safety becomes limited or erased all together. In the effort to avert future impacts and to sustain and improve the transportation systems they steward, transportation agencies nearly everywhere are considering and turning toward climate change adaptation as a solution.

Climate Change Adaptation Defined

Adaptation is broadly defined in global environmental change research communities as all cultural, economic, political, and physical approaches a society implements to reduce the burdensome and devastating effects of current and projected climate regimes on natural, built, and social systems. This concept is understood as an iterative process in which harmful hazard conditions are mediated with available capital and social resources to maintain or acquire a desired advantage.

Climate change adaptation measures fall into several categorical types, including reactive, autonomous, planned, or a combination thereof, depending on the factors that motivate their implementation. Typically, reactive adaptation is characterized by unplanned, under-resourced, and often ineffective responses to an immediate hazard crisis. It provides short-term relief rather than long-term protection and resilience to quantitatively and qualitatively more impactful events that occur in the near and distant future. With reactive measures

or quickened hazard responses comes also the possibility of exacerbated physical and social vulnerabilities to extreme weather and climate impacts, as managers may not hold a position to fully consider and account for each possible decision outcome with the narrow time they possess. Highly independent responses on the part of institutions, firms, neighborhood communities, and households are said to be autonomous.

Since it is approached independently—and reactively in some cases—autonomous adaptation carries strong potential for creating individual, communal, and institutional conflicts in the present and future. In comparison to the aforementioned, planned, or what is also known as proactive, adaptation is perhaps the most ideal and desirable. Planned adaptation involves greater and more conscientious use of space and time to investigate place-based and social vulnerabilities, brings together communities and institutions to discuss and weigh decision-making consequences, and enhances their ability to acquire and utilize resources toward dealing effectively, efficiently, and cooperatively with climate impacts long before they are encountered.

Transportation System Vulnerability

In a global society, the interconnections and interdependencies of transportation systems interact in complex and complicated ways where the weaknesses and failures of those in one locale are shared and even driven by those in another. This creates cause for concern among practitioners, policy makers, scientists, and citizens because the fates of environment and society are firmly intertwined. Scientific evidence indicates that extreme weather is spreading in magnitude and impact as a result of natural and human-caused climate change. Likewise, polar glaciers are melting due to the effect of warming and rising seas.

The force of these trends is demonstrated through higher hurricane and cyclone intensities and elevated storm surge heights that produce spectacular coastal and inland flooding in the Eastern and Western Hemispheres. At highest risk are transportation systems located in the middle latitudes where hurricanes and cyclones commonly occur; they suffer high degrees of wear and tear due to environmental and population pressures, and transportation agencies face overwhelming fiscal,

political, and operational challenges in maintaining and operating them on a near daily basis.

Transportation systems are constantly exposed to weather and climate impacts. All bridges, roadways, airport runways, tunnels, rail networks, etc., are subjected to ambient air temperatures, making them highly susceptible to freeze–thaw weathering and short- and long-wave cooling and heating periods that can cause them to destabilize, buckle, and break altogether. For example, softening permafrost—upon which most of Alaska's road, airstrip, and bridge foundations rest—due to rising global temperatures leads to subsidence that causes transport infrastructure to tilt and eventually break apart. For London's Underground rail system, Brian Arkell and Geoff Darch found higher incidences of rail buckling, service delays, and financial costs during the city's hottest summers. Also, temperatures on subway station platforms are generally higher compared to above-ground conditions and can affect respiratory health, particularly for commuters with asthma and the elderly who wait for trains where there are low-performing or no ventilation and cooling systems.

Geographic circumstances heavily influence transportation system disruptions and losses. Many systems are closely located near creeks and rivers, in floodplains, and coastal zones as a consequence of human settlement patterns and available land that governments grant through right-of-way privileges to transportation agencies to maintain and expand service. Location is thus a key factor in the vulnerability of transportation systems to climate impacts.

In 2012, for example, Hurricane Sandy, the biggest Atlantic hurricane on record in diameter and second most costly in financial terms, affected 40 percent of the nation's mass transit riders when rain downpours and coastal and riverine flooding ruined a quarter of New Jersey Transit's rail fleet and substantial stretches of its track network, crippled critical nodes in the Port Authority of New York and New Jersey's (PANYNJ) line system, and caused heavy damage totaling in the billions for New York City's Metropolitan Transportation Authority's (MTA) subways. For Rockaway, Queens, the loss of public rail service left thousands of mass-transit commuters isolated for several weeks until the MTA activated free yet limited shuttle service to this coastal peninsula.

Adaptation in Practice

The problem of transportation system vulnerability contains many geographic and spatial dimensions and is being addressed by governmental and nongovernmental institutions through socially and technically focused adaptation approaches. For instance, the U.S. Department of Transportation, Transportation Research Board of the National Academies, and other relevant institutions provide planning and research literature, conference gatherings, and other information-sharing vehicles to public and private sector transportation agencies for dealing with actual and projected climate change impacts. In 2011, the Department of Transportation's auxiliary agency, the Federal Transit Administration, piloted an adaptation assessment program for regional and local mass transit agencies and their institutional partners that served to further individual agencies' planned efforts and to promote and stimulate peer learning.

Executive orders and state legislation in recent years have helped establish stakeholder groups composed of climate scientists, social researchers, corporate firms, planning departments, nonprofit organizations, and members of the general public to foster a generalized understanding about climate change adaptation for different economic sectors (for example, agriculture, ecosystem services, energy, etc.). Vulnerability assessments are conducted and monitored by advanced groups. Modeled after the United Nations' Intergovernmental Panel on Climate Change, the work of state and local initiatives, such as ClimAID, the New York City Panel on Climate Change, New York State Climate Action Council, and others supports the development of stakeholder agreements for climate change adaptation among transportation agencies and their institutional counterparts.

Establishing regional bodies with cooperative agendas remains a challenge across many parts of the United States because of territorialized municipal jurisdictions. The absence of regional coordination has emerged as a critical issue among advocates because adaptations made in one municipality are perceived to produce negative spillover effects elsewhere.

Technical fixes are a rapidly growing and critical aspect of transportation adaptation to climate change. For example, advanced cooling technology that reduces the effects of permafrost thawing on



These raised flood mitigation filters were installed in Queens, New York, after a 2007 storm flooded subway lines. The sculptured subway vents double as public art and can serve as benches.

road surfaces was developed and piloted through a collaborative agreement between Alaska's Department of Transportation and Public Facilities and the University of Alaska. Inventive street furniture designed to raise the heights of sidewalk vents to prevent future subway tunnel flooding was the response of New York City's MTA to a thunderstorm in August 2007.

Step-ups were also placed at entrance locations to lessen water infiltration for subway stations. Vent shaft systems manufactured by the for-profit firm FloodBreak and balloon plugs designed by the Northwest National Laboratory and U.S. Department of Homeland Security's Science and Technology Directorate to hold back floodwaters represent the next generation of flood control solutions for the protection of subway systems from intensifying and more frequent heavy precipitation events.

For bus systems, commuter exposures to harmful sun rays, storminess, and variable temperature extremes are amplified by the absence of waiting shelters at passenger pickup locations. In urban, suburban, and rural environments, this is a common occurrence due to their physical demand and capital supply challenges. In Palm Beach and Broward Counties in Florida, federally sponsored economic stimulus initiatives in recent years have enabled these municipalities to reduce bus riders' vulnerability to weather and climate stress through the purchase and installation of much-needed shelters in neighborhood communities.

Innovative technologies that monitor, communicate, and manage climate hazard risk have grown ubiquitous among transportation agencies. Managers of operational control centers turn to national, state, and local climatological and meteorological reporting instruments to decide whether, where, and when to provide public access to transportation systems when extreme weather patterns accumulate. A large number of public transportation authorities transmit weather-related travel advisories and voluntary and involuntary transit system disruptions through Web sites and Short Message Service (SMS) texts to the general public. Although not directly motivated by climate change or extreme weather impacts, the Southeastern Pennsylvania Transportation Authority's (SEPTA) in-house-designed digital TransitView application provides customers with real-time bus and trolley route information and gives the agency added ability to manage their service expectations. SEPTA and other similarly situated agencies have also found GPS technologies to be of purposeful benefit toward ordering and organizing transit vehicle operations, enhancing system resilience, and curtailing equipment maintenance and damage costs.

In-house organizational assessments are a key yet underdiscussed aspect of transportation adaptation to climate change. The realization of hidden assets and capacities to reduce climate vulnerabilities likely saves costs in planning time, effort, and resources. For instance, PANYNJ discovered that prior and unrelated capital improvement investments yielded unintended benefits toward addressing projected impacts while conducting a climate change vulnerability assessment. The installation of new barriers and walls for security projects is

now understood by PANYNJ to provide added protection to possible storm surges for its vulnerable infrastructure. Asphalt mixes developed by staff engineers were found to be resilient to vehicle load and extreme temperature stress. Blackouts in recent years resulted in the agency's linking electrical substations to create redundancies that safeguard against future incidents. This technological hazard response is believed to reduce interruptions in electric service from increased cooling demand in a warming world.

Finally, the real-world practice of transportation adaptation to climate change has outpaced scientific research. Peer-reviewed journals have published a mere handful of studies in recent years that deal directly and solely with the topic. At present, scientific knowledge largely consists of research that classifies different actors and their proposed roles in adaptation, evaluates transportation managers' awareness of climate change impacts on transportation systems, and demonstrates the application of methods to visualize adaptation opportunities for short- and long-range transportation planning.

Potential Impacts on Environment and Society

With all the social, economic, political and technological benefits it is intended to create, transportation adaptation to climate change has foreseeable downsides as well. As stated earlier, there are numerous ways to adapt transportation systems to extreme weather and climate change trends, ranging from the abandonment and relocation of hard infrastructure assets (for example, rail lines, stations, etc.), modification of natural environs, and shift or closure of route service, to the use of mobile technologies to announce voluntary system shut-downs for stormy weather and mainstreaming climate change into state-of-good-repair practices, to name just a few. The open nature of transportation systems, however, makes adaptation outcomes highly unpredictable.

Meteorological and physical change processes are dynamic and interact in surprising ways. There is the high likelihood that adaptation for one transportation system can produce vulnerability in another because they vary in size, design life, material composition, age, and population use. Furthermore, adaptation has unpredictable effects for different social groups, places and economic

sectors because their exposures, sensitivities, and adaptive capacities to system disruptions are highly uneven.

Transportation adaptation to climate change invites incalculable risk and impact potential, which can limit and undo complexly linked goals of environmental protection, urban economic development, and hazard safety and risk mitigation. For example, trees are vital to the strength and balance of natural as well as urban ecosystems. Tree-cutting and removal programs aimed at preventing downed energy-transmission lines for rail operations from weather-induced tree toppling can potentially increase stormwater runoff and accelerate the generation of soil pollutants that spill over into fisheries and recreational areas for swimming. Such programs also conflict with efforts aimed at slowing and reversing human-caused global warming, as trees absorb carbon dioxide, a leading greenhouse gas contributor.

New facility construction and retrofitting projects can reconfigure travel spaces and flows in cities and their close-in suburbs to unwanted economic effect for business firms, hourly wage workers, and others who depend on hassle-free transportation routes for financial stability. People who depend on mass transit and possess limited or no access to mobile technologies run the risk of being stranded at bus stops and rail stations not equipped with public address systems when voluntarily and involuntary service disruptions occur.

Adaptation planning and implementation approaches that emphasize social and economic equity can help advance the goals and principles of environmental justice campaigns that center on the construction of hazard-ready, sustainable, and resilient communities. For planners, policy makers, and all of the agencies responsible for stewarding transportation systems that serve urban, suburban, and rural communities, dealing with climate change impacts will be an important task and challenge for them and for the general public to handle in the months, years, and decades to come.

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See Also: Bridge Design; Bridge Maintenance, Repair, and Replacement; Buses; Climate Change, Transportation Impacts From; Economic

Development; Emerging Technologies; Environmental Impacts; Environmental Justice; Fiscal Politics; Globalization; Green Transportation; Regional Transportation Planning; Subway Systems; Sustainable Transportation; Transit Planning, International; Transportation and the Disadvantaged; Transportation Planning; Tunnels, Safety and Security Issues in.

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Climate Change, Transportation Impacts From

Research indicates that average global temperatures are increasing. The 10 hottest years on record have occurred since 1998. The hottest year for the contiguous United States was 2012. The hottest La Niña year globally was 2011. Tied for the hottest years globally were 1998 and 2010. March 2012 broke 30,000 heat-related temperature records. Arctic sea ice melt accelerated during the past three decades and reached its lowest extent in 2012. General circulation of the atmosphere and precipitation patterns have been altered with a general decrease in precipitation at lower latitudes that already are arid and semi-arid and a general increase in precipitation in middle- and high-latitude locations. Extended droughts prevail in some areas, with more frequent flooding in others.

Higher temperatures cause greater evaporation from both soils and from water bodies. Dry soils and heat-stressed vegetation contribute to a greater number and intensity of forest fires. The smoke and low visibility from fires causes massive traffic pile-ups and has prompted highway closures. The increase in evaporation from water bodies adds water vapor to the atmosphere, which fuels storms. Superstorm Sandy and Typhoon Bopha were fueled by higher sea surface temperatures and higher amounts of water vapor in the atmosphere. Superstorm Sandy flooded the subway system of Manhattan in New York City in 2012. Adding heat to the climate system has resulted in a greater number of severe weather events and a significant increase in operating expenses for the transportation industry.

Aviation

Diversions and cancellations of commercial flights result in hundreds of millions of dollars that the U.S. airline industry loses annually largely due to extreme weather. In the northern United States, delays of aircraft full of passengers due to snow and ice accumulations on runways continue to make the headlines. Aircraft accidents can be caused by high winds such as those that accompany severe thunderstorms, and storms are strengthened by unstable conditions that often result from surface heating. Reports from the National Transportation Safety Board show that weather was a causal or contributing factor in 21 percent of the documented 19,562 aircraft accidents between 1994 and 2003. In 83 percent of the accidents involving commercial air carriers, turbulence and wind were responsible. General aviation accounted for 87 percent of all weather-related accidents.

A microburst, which is a localized downburst from a cumulonimbus cloud, is the deadliest of wind-induced aircraft accidents. Since there is very little air space in which to recover, microbursts are especially deadly during takeoffs and landings. There were 26 commercial aircraft accidents and 620 deaths attributed to microbursts between 1964 and 1985. Yet since 1995, numerous airports and all major airlines in the United States have adopted wind shear detection equipment, which has reduced the accident rate substantially. An additional concern for the aviation industry is the location of its airports. Numerous seaports and airports around the world are located near the coasts. With higher sea surface temperatures and thermal expansion of the oceans, sea level rise poses a serious challenge to transportation infrastructure. In conjunction with thermal expansion, scientists are monitoring the movement of glaciers flowing seaward from large ice sheets. This dynamic contribution of freshwater could result in sea level rise of several meters (20 feet). It is estimated that more than half the human population lives within 60 miles of the sea.

Ground Transport

Climate change is forecast to further intensify tropical storms and cause more frequent outbreaks of violent weather with the associated heavy precipitation and winds. Intense surface heating destabilizes the atmosphere and can contribute to heavy rains that are capable of flooding extensive geographic



Hurricane Sandy, the largest diameter hurricane ever recorded in the Atlantic, wreaked havoc on the transportation systems of New York and New Jersey in late 2012, disrupting travel for a full 40 percent of all mass transit riders in the United States. The ramps shown above in Jersey City, New Jersey, on April 18, 2013, had previously been used by ferries at Liberty State Park to carry passengers to Ellis Island and the Statue of Liberty, but they were mostly destroyed by the storm.

areas. Heavy rains also destabilize steep slopes, initiating mass-wasting events such as the mudflows that commonly plague the Pacific Coast Highway in California. Heavy precipitation is a major contributor to automobile accidents.

Transportation problems that are directly affected by increasing global temperatures are abnormally hot days, which are becoming more frequent and extreme. Railroad tracks warp and buckle during significant heat events, sometimes causing train derailments. Concrete highways undergo joint buckling, creating hazardous conditions for motorists, while asphalt roadways are subjected to softening. Approximately 30 billion tons of carbon dioxide is added to the atmosphere annually. Transportation are responsible for approximately one-quarter of greenhouse gas emissions globally and these emissions are growing more rapidly than

those from other sectors. Of that 25 percent, road transport accounts for approximately 70 percent, shipping is responsible for approximately 20 percent, and air transport for 10 percent.

Shipping

In the summer of 2007, the sea ice of the Arctic shrank to its minimum up to that time. The Northwest Passage opened, which connected the Pacific with the Atlantic Ocean north of Canada's Northwest Territories. Russia planted its flag on the sea floor at the North Pole, Canada decided to open new Arctic bases, and offshore development began. While warmer temperatures melt permafrost on land in the Arctic, which inhibits ground transport, shipping industries are viewing the Northwest Passage for mineral exploration and more commercial operations.

As the Great Lakes shipping season begins for 2013, hydrologists warn that shippers should expect low water levels and that they might have to leave some cargo at the dock. In January 2013, water levels in Lake Huron and Lake Michigan reached record lows, with a monthly mean of 576.02 feet. While it is anticipated that they will not break the January record, the water levels are forecast to be well below the long-term average. While all the Great Lakes are below their long-term average and are expected to remain so for the first half of 2013, Lakes Michigan, Huron, and Superior have been below average for 14 consecutive years—the longest duration in history. Low water levels impose navigational hazards for commercial carriers, along with economic ramifications for all Great Lakes interests such as marinas and waterfront restaurants.

Transportation infrastructure is designed, built, and functions in accordance with local climate conditions. In the *Special Report on Emissions Scenarios*, the United Nations Intergovernmental Panel on Climate Change (IPCC) modeled possible future climates based on the decisions made by policy makers and societies. In each of the future scenarios, there is likely to be a negative impact on moving goods and people. The more greenhouse gas emissions are reduced and the sooner the reductions take place, the better chance there will be to keep transportation networks viable.

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See Also: Air Pollution/Air Quality; Airports, Environmental Issues and; Climate Change, Transportation Adaption to; Environmental Impacts; Environmental Justice; Green Transportation; Health Issues; Railroad Industry, Economics of; Ships; Sustainable Transportation; Transportation Planning.

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Collector Streets

The U.S. Federal Highway Administration (FHWA) divides roads into urban and rural based on census designations of urban and rural areas. Urban and rural roads are further designated into three distinct functional classes: arterials, collectors, and local streets. Each function class is based on the type of service the road provides to the motoring public, and the designation is used for data and planning purposes.

The arterials include interstate highways, freeways, and other highways. They connect the nation's major urbanized areas and cities. As the name suggests, collector streets "collect" traffic from local streets and feed it to higher-function roads such as highways. They often connect key community functions such as schools and major commercial establishments in both urban and rural areas.

The local streets include all access roads and neighborhood-level streets. About 11 percent of roads in the U.S. highway system are labeled arterials, 20 percent collectors, and the rest local roads. Design and construction of these roads are dictated by design manuals from federal and state departments of transportation, which specify various standards.

The functional classes of roads can be changed based on changes in traffic and local land uses. Recent trends show that inclusion of "complete street" concepts are increasingly applied to arterial, collector, and local road designs. The construction and redevelopment of these roads are funded through a combination of federal, state, local, and private funding sources.

Functional Classification

Within urban areas, arterials are divided into principal arterial and minor arterial. These roadway categories vary based on the roadway's relationship between mobility and land access. Here, mobility is defined as the ease of movement between points, whereas land access is defined as access to specific properties.

Arterials emphasize a high level of mobility for through movement, whereas local streets emphasize the land access function. Collectors offer the middle path—relatively equal importance to mobility and land access. There are overlaps of function and mobility characteristics between arterials and collectors as well as between collectors and local streets.

Classification is based on a number of factors such as area characteristics (rural or urban), population served, land use in the area, vehicular traffic (measured as vehicle miles traveled, or annual daily traffic), length of the road, and spacing, among others. Arterials provide the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control. The longer a street is, the more likely it is that the street will function at a higher classification.

Typically, arterials will have annual daily traffic (ADT) of more than 10,000. Principal arterials, particularly in urban areas, carry the majority of traffic entering and leaving urban areas, bypass traffic, and other major intra-area movements. They include the entire federal interstate highway system and other urban freeways and expressways. Minor arterials interconnect with and augment the principal arterial network.

Collectors “collect” vehicles from local roads and feed to arterial routes for longer travels or other collector roads. Typical ADT on collector roads is about 1,000 to 10,000. Local roads primarily serve access to homes and commercial/office establishments. They carry less than 1,500 ADT.

Changes in Functional Classification

The federal Highway Performance Monitoring System (HPMS) measures vehicle miles traveled (VMT) by functional class and can be used to understand driving patterns on each class, land development pattern in a region, and the potential damage to the pavement. Traffic patterns on a roadway and the roadway's function can change over time.

The FHWA and state Departments of Transportation (DOTs), with the help of metropolitan planning organizations (MPOs), review suggestions for redesignation and make appropriate changes. Municipalities and county governments can submit such suggestions based on the land use changes or traffic pattern changes in their jurisdictions. The decision to change classification will be based on careful review of changes in conditions and sound reasoning. Such changes can have implications on design of roads and federal and state funding.

Characteristics of Roads

Usually, access to principal arterials is fully controlled and allowed only at interchanges. Directional travel lanes on these roads are usually separated by some type of physical barrier. They are designed and constructed to maximize their mobility function, and abutting land uses are not directly served by them. Other principal arterials have partial access control, which means they can also be used to access abutting land uses. Minor arterials may not have access control.

Generally, bicycles and pedestrians are not allowed on major arterials. In urban areas, major arterials could carry as few as 7,000 vehicles a day. In rural areas, this minimum is 2,000 vehicles a day. Corresponding values for minor arterials are 3,000 and 1,500 vehicles per day.

The collector streets are divided into major and minor collectors. They support both mobility and access functions in nearly equal measure. Major collectors typically have greater right-of-way and pavement widths, and wider traffic lanes than minor collectors. They generally have traffic signals and left-turn lanes at major intersections and driveways.

They also provide raised medians in busy areas to reduce conflicts and provide pedestrian refuge. They usually have sidewalks, planting strips, and bike lanes. They could carry as few as 1,000 vehicles a day in urban areas. Left-turn lanes are only sparingly used on minor collectors, mostly at intersections with higher volume streets. Though they might have sidewalks and planting strips, bike lanes are not necessary. Typically, bikers share the road with auto traffic.

In rural areas, minor collectors could carry as few as 150 vehicles a day and major collectors might carry as few as 300 vehicles a day. Collector streets are also

used as important emergency response routes and are frequently used as transit routes.

Local roads account for the largest percentage of all roadways in terms of mileage. They are intended for accessing land parcels from collectors and vice versa. Bus routes, bicycle paths, and sidewalks generally do not run on local roads and they are the narrowest streets among the three classes. There is no access control or division between lanes in opposite directions. They usually carry no more than 750 vehicles per day.

Highway planning and design process consider the functional class as a first step. A determination of functional classification establishes the basic roadway cross-section in terms of lane width, shoulder width, type and width of median area, and other major design features. Design manuals suggest different ranges of these factors for different functional classes. Typical speed limits range between 20 and 35 miles per hour (mph) while the number of lanes varies typically from two to four.

The reference most often used by road designers in the United States during the design of a road project is commonly referred to as the Green Book, published by the American Association of State Highway and Transportation Officials (AASHTO). Its actual title is *A Policy on the Geometric Design of Highways and Streets* and it provides a series of guidelines on geometric design with some amount of flexibility allowed.

The FHWA has adopted applicable parts of the Green Book as the national standard for roads in the National Highway System (NHS) that comprise all the interstates and some other primary routes. The design of roads other than those in the NHS is subject to the standards of the particular state.

“Complete” Streets

Roads should be interconnected, especially in the suburbs where a grid pattern is not present. This allows for more travel route choices and reduces costly widening or changes in other streets. Such an interconnected system improves the value of properties and affords multiple paths of ingress and egress for emergency response and other services.

Recently, the concept of “complete streets” has gained much traction with communities and transportation agencies. A complete street provides for the safe, convenient, and comfortable travel for all modes of travel, including walking, bicycling,

transit vehicles, and automobiles. The streets are safe for people of all physical and cognitive abilities, such as those in wheelchairs or who have low vision. This is accomplished through good design of the street, including interconnected sidewalk and street crossings.

Traffic calming solutions are also applied in street designs, especially on collector and local roads. Such street design is expected to increase the quality of life in a community. It is also argued that incorporating design elements that are supportive of walking, cycling, and public transportation increases the economic and social viability of adjacent land uses. Thus, these treatments enhance the livability (quality of life) and safety of neighborhoods.

Funding for Roads

There are many fund sources for new construction or reconstruction of roads in the United States. One of the major fund sources is the National Highway Performance Program (NHPP), which provides support for the maintenance of and addition to the Interstate highways and National Highway System (NHS). NHS includes all arterials. Funds can be used for construction, repair, and replacement, of roads, bridges, tunnels, bicycle/ pedestrian facilities, safety improvements, etc.

Another major funding support is the Surface Transportation Program (STP). The STP provides funds for projects not in the Interstate System or the National Highway System (NHS). STP-Urban funds are intended to benefit minor arterial and collector roads in urban areas. Funds can be used for a wide range of projects, including roadway widening, roadway reconstruction, and transit projects. The STP-Enhancement Program is designed to help expand transportation choices and enhance the transportation experience.

Federal regulations define categories of eligible activities, including pedestrian and bicycle infrastructure and safety programs, scenic and historic highway programs, landscaping and scenic beautification, historic preservation, and environmental mitigation. Highway Safety Improvement Program (HSIP) funds projects that reduce traffic fatalities and injuries on all public roads.

The Congestion Mitigation and Air Quality (CMAQ) program addresses congestion and air quality problems. Funds must be used for projects that reduce congestion and/or vehicular emissions

and are intended to help achieve the goal of the 1990 Federal Clean Air Act Amendments. Eligible projects include traffic signalization, incident management, and rail/bus transit. In addition, federal and state bridge programs provide funds for bridges on collector roads that meet certain criteria. Municipalities explore innovative financing techniques, including developer-funded road development and general traffic impact fees.

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See Also: Access Roads; Accessibility and Mobility; American Association of State Highway and Transportation Officials; Complete Streets; Congestion Mitigation and Air Quality Program; Federal Highway Administration; Traffic Calming.

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Collision Avoidance Systems, Airplane

Collision avoidance involves prevention of unwanted contact with other planes, obstacles, or the ground. Over half of midair collisions occur within 5 miles of an airport; 96 percent occur below 3,000 feet, and 40 percent occur below 500 feet. Most happen during the day; less than 2 percent occur after sundown. Most are in the traffic pattern, and high-speed head-on collisions account for only 14 percent of midair collisions. Side impact accounts for 39 percent, with 47 percent due to one plane overtaking another. Some routes and major commercial hubs are congested airspace, and

midair collision risk increases with volume of aircraft in finite space. Commercial airlines continue to add new aircraft to an already congested system.

The first layer of accident avoidance is proper operational procedures. Traffic is assigned lanes—a specific airway at a specific altitude for each craft—and air traffic controllers monitor the various craft and lanes to predict and prevent conflicts. Standard distances are 3 to 5 miles laterally and 1,000 feet vertically. Air traffic controllers advise pilots of measures to take as surrounding traffic dictates. When air traffic control (ATC) fails, an airborne collision avoidance system takes over, giving the pilot what it takes to avoid the collision.

Types of collision avoidance systems include airborne radar (available since World War II), but nonmilitary aircraft that routinely have weather radar rarely carry sensitive anticollision radar. An airborne collision avoidance system (ACAS) may be defined as a system on the aircraft working independently of air traffic control and ground-based equipment to warn pilots that other aircraft are in position for a potential collision. The system may, if the danger is imminent, suggest a maneuver to avoid the collision.

ACAS standards are published in the Convention on International Civil Aviation, annex 10, volume IV. As of 2009 only two versions of the Traffic Alert and Collision Avoidance System (TCAS II) met the International Civil Aviation Organization (ICAO) standard.

ACAS differs from the airborne separation assurance system (ASAS) in that ACAS means a short-range system for prevention of metal-to-metal collisions. ASAS pertains to longer range systems to preserve standard en route separation of 5 nautical miles (9.25 kilometers) horizontal and 1,000 feet (305 meters) vertical.

Airborne collision avoidance systems have the goal of providing the pilot adequate information to take appropriate action in a dangerous situation. Current collision avoidance systems offer proximity warning (PW), traffic advisory (TA), and resolution instruction (RI). PW says an aircraft is near, TA says a particular plane is a threat, and RI tells what to do to avoid the threat.

PW devices were used in the early 1950s, but they quickly became inadequate to handle the increased volume and associated increased collision risk. Collision avoidance systems of various sorts were tried

from the 1950s to the mid-1980s, at which time the TCAS became the standard.

In 1956 a Lockheed Constellation and a DC-7 collided in visual flight conditions over the Grand Canyon with a loss of 128 lives. The collision led to demands for modernizing the air traffic control system, producing the current system for preventing midair collisions. After the Grand Canyon collision, in the 1950s and 1960s the FAA allowed various approaches to collision avoidance before settling on the Beacon Collision Avoidance System (BCAS), an airborne transponder system, in 1974. In 1978 over San Diego a Boeing 727 and a Cessna 172, both under radar control, collided and 144 people died. Restrictions on flight in heavy traffic areas were tightened. The San Diego collision of 1978 led to an expansion of the BCAS, renamed TCAS in 1981.

Traffic Alert and Collision Avoidance System

The Traffic Alert and Collision Avoidance System is a means of actively interrogating other transponders and establishing collision avoidance tactics between two affected planes. TCAS is expensive and used mostly by larger airplanes. TCAS works only if both potential colliders have functioning transponders with altitude reporting.

A collision between a DC-9 and a Piper Archer at Cerritos, near Los Angeles, California, on August 31, 1986, killed 82 people in the air and another 15 on the ground, and the National Transportation Safety Board (NTSB) blamed an inadequate air traffic control system. The Cerritos collision of 1986 led to a congressional mandate in 1987 through the Airport and Airway Safety Expansion Act that the Federal Aviation Administration (FAA) require TCAS on all turbine-powered craft equipped with more than 30 passenger seats by 1992. Congress later extended the deadline to 1993.

The first TCAS on commercial planes began flying in 1990. TCAS was at least partially responsible for the drastic reduction of midair collisions, with none in a decade after implementation. In 2003 the TCAS became mandatory worldwide, and in 2005 the coverage was extended to all planes with over 19 seats or a maximum takeoff weight of 5,700 kg. The TCAS is installed on over 25,000 aircraft worldwide. Since implementation of TCAS, midair accidents have diminished to only one every 100 million flight hours. No TCAS-equipped airplane

has been involved in a fatal collision in the United States. In 2006, however, over the Amazon in Brazil, a Boeing 737 collided with an Embraer Legacy 600 business jet. Even TCAS is not 100 percent sure.

It has to be reliable to ensure that pilots do not lose faith in it due to false alarms or, worse, collide due to missed or delayed threat warnings in a high-density, high-speed air traffic system. In 1973 the FAA transponder minimum performance technical orders had errors pertaining to radar beacons and traffic alert and collision avoidance system capability of detecting aircraft transponders. The "terra problem" has persisted, leading FAA to advise manufacturers of transponders to modify their products to allow them to work with newer radars and TCAS systems.

Because the standard remains flawed, the solutions have created different capabilities by make and model of transponder. A proposed modification requiring a transponder to respond to all radars and TCAS will eliminate problems with saturation in high-density areas, eliminate interference with TCAS and ATC radar, and comply with the international standard.

Relatively Inexpensive Systems

The TCAS, a high-end traffic advisory system (TAS), covers 20 miles and is mostly used for business and charter planes, larger than average general aviation planes. TCAS offers suggested avoidance actions, such as climb or descend for example. TCAS was expensive, costing up to \$40,000, and excepting corporation and charter operations, general aviation planes rarely had it, meaning that almost monthly there was a fatal collision involving the smaller planes.

Finally, Cirrus Design Corporation and others began developing lower cost accident avoidance technology for general aviation, at a minimum a passive receiver that allowed a plane transponder to signal its presence and other planes to receive the signal. A system costing around \$1,800 had the capability of detecting craft six miles away and 2,500 feet above or below, but coverage still has blind spots.

The portable collision avoidance system (PCAS) is a cheaper but passive TCAS available for general aviation aircraft. Rather than interrogating other aircraft as TCAS does, PCAS listens to responses from other interrogations. Like TCAS, it depends

on both parties having functioning transponders with altitude reporting.

Better systems, such as the traffic information system (TIS), have data links from the plane transponder to a ground-based radar network that offers data for a 5-mile radius 1,200 feet above or below, but it is limited to congested traffic areas. The traffic advisory system (TAS) provides active searching of airspace for transponder-equipped planes. This technology handles up to 30 planes in a 2-, 6-, or 12-mile radius, 10,000 feet above or below the plane, and it offers audible and visual warnings of aircraft on potential collision courses. TAS systems at this level can be as cheap as \$10,000. TAS and TIS are becoming standard in new general aviation craft, and units for retrofitting older planes are available.

Light Aircraft

Gliders and comparable light aircraft use a lightweight, easy to install, and inexpensive system known as FLARM to broadcast their position and speed over radio. FLARM also listens to other similarly equipped craft and computes short-term conflicts, advising the pilot by sound and sight. FLARM will not warn of obstacles lacking a FLARM device. The FLARM Web site indicates that 17,000 FLARM systems are in use worldwide.

Other Systems

The most costly plane collision was not in the air but on the ground. In 1977 two Boeing 747s collided on the runway at Tenerife, Canary Islands, with a loss of 583 lives. Since 2003 an average of seven runway incursions a year have occurred, and the majority are caused by general aviation craft.

Other systems include a ground proximity warning system available on larger general aviation and civil airliners to track ground elevation below the craft. Terrain Awareness and Warning System tracks potential obstacles such as tall towers or mountains in the flight path. Synthetic vision offers a computer simulation of the environment outside the craft in low or zero visibility conditions. A ground-based obstacle collision avoidance system uses radar on or near the obstacle to detect approaching aircraft and warn them away. Large and sophisticated craft may employ all or some of the systems, whereas a small general aviation craft may have only one.

In the future, automatic dependent surveillance-broadcast (ADS-B) will free aircraft from dependence on ground-based radar, using instead the Global Navigation Satellite System to exchange information with other aircraft and air traffic controllers. Pilots using the new technology will not have the negative effects of topography or distance, but it depends on the other craft being on the same system, so until it is universal it is ineffective. The FAA has not yet determined how to provide all its ground-based controllers the new technology and how to get all airplanes to use the system. A test of ADS-B is under way in Alaska.

One solution under study is a fuzzy-based system that warns of potential midair collisions and takes control of the aircraft if the pilot fails to respond in a timely fashion. The fuzzy system would divert the craft from its pre-established route in bad weather or heavy traffic.

Pilot Awareness

Some small planes rely solely on the pilot's awareness of his environment. Although general aviation (GA) safety in general has improved over time, there is no corresponding decrease in midair collisions. They maintain at a rate of one a month on average, some with single fatalities or none but others with multiple fatalities. GA also have a tendency to collide on the ground because two aircraft are in the same runway space. The solution to this is for the pilot to start watching for other traffic as soon as he starts the engine instead of waiting until he or she has taken off.

In visual conditions the key accident avoidance system is the pilot. Pilots learn during training to keep their eyes on traffic. Pilot awareness is also critical for commercial pilots with all the latest technology. TCAS is merely an advisory system because it cannot incorporate terrain, weather, traffic not online, and air traffic control instructions. Until the plane has the capability for autonomous collision avoidance, the pilot remains obligated to watch for intrusions.

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See Also: Air Traffic Control; Airplane Disasters; Aviation, Private; Aviation, Ultralight; Aviation Safety, Wildlife Strikes and.

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Collision Avoidance Systems, Automobile

As traffic volumes continue to rise in the United States, collision avoidance systems (CAS) have played a large role in reducing the severity of, and in some cases preventing, automobile accidents. These safety systems use radar or cameras to detect an imminent crash.

The risks of traffic accidents are relatively high. The National Highway Traffic Safety Administration estimates that 15 to 20 percent of reported accidents involve rear-end collisions, and that 88 percent of rear-end collisions are caused by drivers not paying proper attention to the road. There are different ways in which these collision avoidance systems improve traffic conditions, including using radar to reduce collisions, detecting slow or stranded vehicles, automatic braking systems, cruise controls, and automated toll collection devices so drivers can avoid stopping at toll booths and creating a dangerous line of traffic. The development of CAS shows a trend in preventing crashes

rather than simply developing stronger car frames, seat belts, and air bags to cope with the problem.

How They Work

Collision avoidance systems have evolved greatly over the years, although in their simplest form, they contain a sensor at the front end of the vehicle that scans the road for obstacles and monitors the distance from obstacles (cars) in front of the driver. Automatic brakes are applied when the system determines the vehicle is in danger of crashing into an object or another vehicle.

The system is switched on under different criteria. Time-to-collision criteria predicts a crash will occur at the current speeds and distances within a certain time interval. For instance, if two cars are traveling and maintain their current speeds, the point at which they will collide is the time-to-collision. Another instance is referred to as the worst-case criterion, which assumes that the vehicle in front of the CAS-equipped vehicle could use its brakes at full capacity at any time, which would then likely cause a crash.

CAS-equipped vehicles use various maneuvers to prevent an accident. Headway distance control warns the driver whenever the vehicle is following the leading car too closely. A hazard warning alerts the driver of an object, whether it is moving or stationary, within its projected path so the driver has ample time to avoid the crash. Lastly, automatic vehicle control takes over a car's brakes and steering and applies them automatically when it feels it is necessary.

When the CAS warning is deployed, the driver is made aware of this in a number of ways. Visual heads-up displays appear on the windshield in the driver's field of view so that their content can be assimilated in conjunction with the driving scene ahead. This is intended to minimize distractions to the driver. Audio and voice signals are considered to be less intrusive while driving than visual heads-up displays and can be heard despite lighting conditions, which can affect visual heads-up signals.

The bases of all collision avoidance systems are divided into three different types: optical techniques, electromagnetic techniques, and acoustic techniques. Optical techniques are dependent upon environmental conditions, and laser radar is costly, although also more effective than passive infrared. The electromagnetic technique is the best for

determining long-distance measurement. Acoustic techniques are best for short-term, relative distance measurements.

Sensors should be able to determine the headway distance, the relative speed between the preceding vehicle or obstacle and the equipped vehicle, or both. Ultrasonic technology operates sensors by measuring the time-to-flight of a short burst of sound energy. The time required for the ultrasonic wave to return from the obstacle it detects determines how far away the vehicle is. The headway distance is calculated by measuring the time between transmitting a pulse and receiving a reflection. Passive infrared sensors measure the thermal energy emitted by objects in the vicinity of the CAS-equipped vehicle. These sensors are not as costly but also cannot detect the distance to an object with accuracy.

Two techniques exist within laser radar: one using a high-power pulsed-beam of infrared light and one where the amplitude of the light is modulated with a sine wave. Frequency modulated continuous wave (FMCW) radar uses modulated high frequencies so that the frequency difference between the reflected and the transmitted signal is proportional to the distance from the object ahead. In addition, the Doppler shift on the reflected signal can be used to determine the relative speed between the vehicle and the object ahead.

Impulse radar uses very short pulses instead of a continuous wave. By using lower frequency electronics, a resolution similar to that of the FMCW radar can be obtained, and at a fraction of the cost. Capacitive sensors are able to detect close objects using the capacitance variations between electrodes excited at low frequencies. Despite their limited range, they are low in cost and immune to external environmental effects. Vision system techniques are based on the use of a video camera and image-processing software.

Effectiveness

Studies show that collision avoidance systems are highly effective, and consumers should consider vehicles equipped with them. An analysis of insurance claims from the Highway Loss Data Institute, an affiliate of the Insurance Institute for Highway Safety, showed that forward-collision warning systems alert the driver if they are approaching traffic ahead at a rate faster than the cars ahead of them. Automatic braking along with adaptive headlights,

which respond to a vehicle's speed and direction of the steering wheel to help direct the lights onto the vehicle's intended path, are proven to be very effective in lowering crash and accident claims.

One feature, however, appeared to have increased the risk of an accident. Lane-departure warnings, which tell drivers when it is unsafe to leave their lane if they are drifting or considering merging, were found to be unsafe and increase the number of injuries. CAS features are beginning to make their way into all new fleets of cars and many lines mandate their use.

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See Also: Automated Traffic Enforcement; Automobile Accident Avoidance Systems; Automobile Accidents and Prevention; Automobile Safety Inspections and Registration; Automobile Safety Systems.

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Commuter Buses

After decades of decline, the long-distance bus industry reinvented itself into a wide variety of markets in the 1990s, including that of commuter buses. A flexible, reasonably priced, and essential means of getting to work for thousands, commuter buses play an important role in America's transportation grid. Enhanced government safety legislation and private companies like Google and Microsoft



This 45-foot commuter bus taking on passengers at the Marin County Civic Center in San Rafael, California, is equipped with wi-fi Internet, like many newer commuter buses.

are making important impacts on the commuter bus industry, and local and state transit authorities strive to implement, maintain, and improve their systems, encouraging people to park their cars and ride the bus in order to reduce traffic congestion and environmental impact.

Specifications and Operational Characteristics

Transit planning boards work with established definitions of commuter buses and their operating routes. When a transportation board or transit company interested in establishing and operating a commuter bus company conducts planning meetings, it has a specification list for commuter buses and their operations. Also called transit buses, city buses, or public buses, commuter buses include low floor, double-decker, articulated, and midibuses (in between a minibus and a full-size bus).

Generally speaking, commuter buses have large and often multiple doors for boarding and exiting. They have bench or bucket seats with no head

rests and minuscule or no luggage space. There is equipment to verify tickets or accept fares, electronic signs or roll signs to display destinations, and a pull cord or bus stop request button. They also feature a legal standing-passenger capacity. Modern commuter buses also come equipped with amenities that match the interiors of private cars—the chief competitors of transit buses—amenities that include computer hookups, televisions, DVD players, and Internet capabilities.

Commuter bus routes are fixed and operate primarily in one direction during peak periods; routes are limited in length usually between a central business district and suburbs on the outer edge of the district. The routes feature limited stops and uses multiride tickets. The commuter bus service may also include other services featuring a limited route, limited stops, and a cooperative relationship with another method of transportation.

Public transit authorities, municipal bus companies, and private transport companies on a public contract or fully independent basis are all operators of commuter buses. Often, commuter buses are built to third-party specifications. The operating area of a transit bus can also be defined as a geographic metropolitan area and, for capital cost reasons, some regional size operators may use transit buses interchangeably on short urban routes and longer rural routes. Often transit bus operators feature standard transit buses fitted with coach-type seating for longer distance routes. At times, transit buses can be used as express buses on limited stop or nonstop service at peak times over the same distance as the regular route.

Planning and Implementation

In its guidebook *Bus Rapid Transit Service Design Guidelines*, the Santa Clara Valley Transportation Authority (in San Jose, California) identifies some guidelines for establishing a commuter bus operation or bringing an existing one up to standard. Creating and operating a commuter bus operation involves comprehensive planning. The first step is an initial planning study to determine the feasibility and structure and identify the local commitments necessary for funding, implementing and monitoring the new service. This includes conducting market research to estimate ridership and revenue potential. Identifying and designing route alignments is an important selling point, and designing

stations, facilities, and necessary street improvements is an important step as well. Developing an operations plan and implementation schedule is crucial, as is developing a marketing plan and brand management strategy. A transit board needs to determine the length of time the new service will be tested and after that to decide whether to retain, drop, or modify the service.

Performance statistics for evaluation routes and stations include boardings per revenue vehicle hour, a measure of the number of boardings during a specific revenue hour of bus service. This figure reveals how well the commuter bus is utilized and indicates whether the commuter bus level of service is appropriate and how well operating resources are used. The number of daily boardings versus the total route length or network is compared to assess whether a route is effectively designed, taking its length and extraneous destinations into consideration. The figures can be used to identify route segments with higher demand, allowing the transit authority to tailor service and capacity.

If a commuter bus service already exists, it is necessary to determine whether existing services meet established service standards. If existing services do not meet established service standards, an improvement plan must be submitted.

New Legislation for Commuter Bus Safety

The federal government recently updated safety regulations for commuter buses by giving the Federal Transit Administration (FTA) authority to enforce a new, comprehensive framework to oversee the safety of millions of passengers riding public transportation every day.

On July 6, 2012, President Barack Obama signed Moving Ahead for Progress in the 21st Century (MAP-21), reauthorizing surface transportation programs through 2014. Effective October 1, 2012, MAP-21 reauthorizes surface transportation programs and amends the federal Transit Laws codified in 49 U.S.C. Chapter 53. The legislation includes many of the new authorities included in the administration's original proposal and also includes important safety provisions for bus-only operators.

Under MAP-21, backed by \$25 million a year in new funding for safety and inspection-related training, transit agencies may discover risks they did not know were as serious as they are, according

to government officials. The FTA will implement MAP-21 in consultation with the transit community, the Transit Rail Advisory Committee for Safety, safety experts from the transit industry, transportation labor groups, and academic institutions around the country. The new standards will replace existing state laws.

In Chicago, MAP-21 will fund new oversight activities designed to provide a close look at issues ranging from vehicle maintenance and track inspections to operations and action plans in response to emergencies. According to Chicago Transit Authority (CTA) officials, the need for tighter supervision is especially needed in the Chicago area because much of the transit infrastructure does not meet state-of-good-repair standards. Until MAP-21, commuters using a combination of the CTA, Metra, Pace, and the South Shore Line and transferring from one system to the other were not covered by a consistent safety net.

Regional, state, and the federal governments can cooperate to ensure the success of commuter buses through existing programs, by revising laws and by funding policies. In 2008, the Metropolitan Transit Authority in New York introduced Select Bus Service System (SBS), featuring more frequent service, especially designed buses with flashing lights, coordinated traffic signs, and an off-board fare-collection system. The federal and state governments cooperated with the MTA to create the system, which operates successfully and with increased ridership.

The Maryland Transit Administration (MTA) sponsors Commuter Choice Maryland, an incentive program that encourages Maryland workers to ride commuter buses or vanpools instead of driving to work. Commuter Choice offers employers monthly pass options to ride MTA local and commuter buses, light rail, metro subway, and MARC Train for reduced fares.

Private Commuter Buses

Among their employee perks, employers like Google, Yahoo!, Genentech, Cisco, eBay, and other technology companies offer private commuter buses that pick up employees close to home and speed them to work, then back home again when the workday ends. The San Francisco County Transportation Authority estimates these luxury eco-buses eliminate about 327,000 solo vehicle round

trips a year from Bay Area roadways, reducing CO₂ and non-CO₂ emissions. Private commuter buses also boost neighbor businesses when commuters shop local stores.

Employers like Google benefit because the private commuter buses help them meet city transportation demand management (TDM) requirements and reduce the company's environmental impact. The buses are a valuable recruiting tool and they increase employee productivity and decrease parking demand.

Not everyone approved of the private commuter buses. Some people complained about the large buses roaring through their neighborhoods and idling on residential streets or that the private commuter buses conflicted with city bus schedules when they loaded passengers or idled at the same bus stops.

Krute Singa and Jean-David Margulici, researchers at the California Center for Innovative Transportation (CCIT), conducted a study of the effects of the luxury commuter shuttles on employees, employers, and residents and on public transportation. One of the conclusions they reached in their 45-page report, *Privately-Provided Commuter Bus Services: Role in the San Francisco Bay Area Regional Transportation Network*, was that public transit agencies and private employers sponsoring commuter buses could work together. They also suggested that regional transportation agencies could formally integrate private commuter buses into their planning. They said that states could promote ride sharing, transit, and alternative modes of transportation, and regional, state, and federal governments could encourage the success of private commuter buses through existing programs, revising laws, and making funding available.

Seattle's Microsoft Corporation took a different approach from that of the San Francisco Bay Area. Instead of sending their private employer buses into residential streets without coordinating with the city, Microsoft's transportation staff met with the King County Metro Transit board and they worked out a system whereby Microsoft's shuttle service, Microsoft Connector, augmented service for employees when it was not available through public transit.

The Microsoft Connector does not compete with King County Metro, which operates a diverse fleet of buses, electric trolleys, streetcars,

paratransit vans, and vanpool programs, but instead the Metro acts as mobility manager, filling transportation gaps and providing a cohesive transportation network. The Microsoft Connector is allowed to use a bay at Metro's bus transit center but is prohibited from using on-street transit stops. Microsoft worked with local churches and businesses to establish stops in white curb zones and parking lots. It averages over 3,400 riders a day over 55 routes, or just under 1 percent of Metro's daily boardings.

The study also suggests that employer commuter buses should receive funding using the action of Massachusetts Bay Transportation Authority (MBTA), as an example. The MBTA acknowledged that it could not provide service to certain outlying areas, but it paid a private company to provide the service, finding it more cost effective to fund private operators than to let them go out of business and be required to provide the funding and service itself.

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See Also: Bus Rapid Transit; Bus Systems, Local and Express; Busways and Reversible Bus Lanes; Transportation Planning.

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Commuter Paradox

The paradox in the commuter paradox refers to the perception that commutes are getting longer (predominantly in time) when that is not necessarily true in reality. For the most part, commuting times in the United States have stayed about the same over the last 30 years. Comparing the United States to the rest of the developed world, the commuting times of those who are employed full-time in the United States are currently not among the longest in developed countries. That distinction belongs to first, South Africa (56 minutes per day), second, Korea (55 minutes per day), and third, Turkey/Japan (48 minutes per day). On the contrary, commuting times in the United States are among the shortest in the world: (1) Ireland (26 minutes per day), (2) Denmark (27 minutes per day), and (3) Sweden/United States (28 minutes per day).

To what, then, can the perception of longer commutes be attributed? The usual culprit is congestion. Indeed, anecdotal and empirical evidence highlight just how ubiquitous congestion has become in metropolitan areas across the United States. What was once a phenomenon that negatively impacted the all-important work-life balance of large-sized metropolitan-area dwellers has come to visit those living in medium- and small-sized metropolitan areas as well. Internationally, congestion is becoming more readily identified as adding costs to the movement of people as well as of goods and services.

If congestion is indeed problematic the world over, then why hasn't it had a direct, negative effect on commuting times in the United States (by making them longer)? In addition, is it reasonable to expect that the commuter paradox won't become a reality in the future? Both of these issues are taken up in the following sections.

Congestion and Commuting Times

One trend that directly impacts congestion, but not necessarily average commuting times, is the distribution of trips. Trips are typically broken down into the following categories: work, shopping, recreation, and social. While work trips continue to be important, it is the increase in the numbers of non-work trips that has had an impact on congestion, especially during nonpeak hours of the day in the United States. The growth in nonwork trips and trip

chaining wherein one trip encompasses any combination of these different trip types has had a direct impact on congestion.

Another trend that has directly impacted congestion is the increase in the number of vehicles per household. Over time in the United States, the number of zero-vehicle households has decreased and the average number of private vehicles (cars, pickup trucks, vans, and sport utility vehicles) per household has increased. This increase in vehicle availability is a sign of several realities in the U.S. labor market.

First, the dual-income household is much more common than in the past and coincides with greater female labor force participation rates. It is also true that the recent economic recession has made it a necessity for both wage earners to have access to a vehicle in order to cobble together several part-time jobs and so maintain household income levels.

Second, because most commutes today are between home and work locations that are both in the suburbs where public transportation is often not available, the private vehicle is often the only viable mode choice for commuters. While there is some evidence that the dispersion of jobs away from more central locations in metropolitan areas across the United States has abated due to the Great Recession, the decentralization of employment to the suburbs has had a direct effect on congestion.

Commuter Paradox and the Future

One explanation for the stability of commuting times in the United States is that firms and households are synchronously adjusting their locations, typically on the periphery of metropolitan areas across the United States, to accommodate greater congestion. These rational actions on the part of commuters to adapt to the decentralization of employment and the most negative effects of congestion help understand the phenomenon known as the commuter paradox.

To follow this explanation to its logical conclusion then, any disruption in the ability or willingness of commuters to continue to adjust their home locations to account for congestion will lead to longer average commutes. Given the brief window of time since the Great Recession, which has had a direct effect on the decentralization of

employment and the ability of homeowners to easily sell and buy within their own real estate markets (because many homeowners now owe more on their mortgages than their homes are worth), it is too soon to empirically verify the rational locator hypothesis. However, given the ubiquity of congestion and the importance of residential real estate to the general state of the U.S. economy, the commuter paradox will continue to be an important topical area of research in transportation and regional development.

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See Also: Automobile Trips; Commuting; Employment Location; Green Transportation; Jobs–Housing Balance/Spatial Mismatch; Noncommuter Travel; Surface Transportation Policy Project; Traffic Congestion; Urban Sprawl Versus Compact Development.

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Commuter Rail

Planners view commuter rail as a means of managing urban sprawl, stimulating economic development, and reducing the environmental impacts of transportation. Commuter rail systems, which use shared rights-of-way to connect suburban hubs

with downtown urban centers, have a large impact on the way people and freight move through many of the larger urbanized areas in the United States. Currently, there are 24 commuter rail systems operating in 29 major U.S. metropolitan areas.

Commuter rail, sometimes called regional rail or suburban rail, is uniquely situated between standard passenger rail and intra-urban rail transit. Commuter rail systems operate frequent and regular services that are scheduled around traditional peak commuting hours. These services are designed to move commuters within the greater metropolitan area and establish a connection between suburban communities and the city center, although a few systems connect adjacent metro areas (such as Dallas–Ft. Worth or Washington, D.C.–Baltimore). Commuter rail systems operate on shared track infrastructure with freight rail carriers and Amtrak passenger rail. These shared corridors usually range between 30 and 200 miles of track, although the very largest systems in the country have up to several hundred miles of track.

Commuter rail systems can be classified using a "legacy" or "new start" dichotomy. There are nine legacy rail systems and 17 new start systems operating in the United States. Legacy systems were previously operated as private commuter rail services but were acquired by public transit agencies after World War II. New start systems are more recently developed commuter rail services established by public transit agencies after 1980.

New start commuter rail systems have been established by public transit agencies using start-up funding from Federal Transit Administration (FTA) grants designed for establishing new fixed guideway transit systems—including commuter rail. While municipal transit authorities acquired legacy systems as a turnkey operation, complete with right-of-way and rolling stock, new start systems have had to negotiate the terms of establishing new shared corridors with freight rail carriers that own the track infrastructure. Some new start commuter rail systems subcontract the day-to-day operations to private companies, such as Herzog Transit Services or Veolia Transportation, but these systems are still under the governance of local public transit agencies.

Based on an urban area's existing infrastructure and previous commuter services, there are three scenarios for establishing new start systems. The

most common scenario is commuter rail being established from the ground up in areas that have recently begun to rapidly urbanize. These systems are designed and built in cities with no previous history of commuter rail service.

The second scenario is the re-establishment of long-dormant commuter lines that were not acquired by public transit agencies after their discontinuance. Some large urban centers had commuter services operating prior to 1950 but whose services were abandoned for several decades before the creation of the current commuter rail service.

The third scenario is the modification of existing passenger rail service to provide commuter rail services. These new start systems expand the capacity of existing Amtrak passenger rail services, allowing a set of commuter express trains to run hourly during peak commuting hours.

Regardless of the start-up scenario, the biggest challenge in planning a new start commuter rail system is the acquisition of a rail corridor from the private freight carrier that owns the track infrastructure. There are three strategies of corridor right-of-way acquisition: (1) purchasing the track infrastructure outright, (2) purchasing an easement along the freight carrier corridor, or (3) leasing a specific number of daily commuter trips on the corridor. While the initial investment is greater, purchasing track infrastructure allows public transit agencies to control the dispatching of commuter and freight trains. This allows commuter rail systems to better control scheduling and ensure higher on-time rates.

Recent increases in commuter rail trips indicate that commuter rail service will continue to grow nationally as more new start commuter rail systems are being established in cities and as ridership grows on legacy systems. Between 1997 and 2007, commuter rail added 100 million additional riders—a 28 percent increase in national ridership. This is the first sustained increase in rail ridership since 1945. Long-term rail ridership had been in a state of decline since World War II, as personal automobile ownership became more commonplace.

In 1962, President John F. Kennedy delivered a special message to Congress calling for planning efforts and capital assistance for U.S. urban mass transit. Departing from the interstate highway-focused planning convention of the time, the

Kennedy administration also asked Congress to conduct a comprehensive study of U.S. intercity transit policy and rights-of-way to facilitate the creation of a national multimodal transit system. This resulted in an effort to address the problem of deteriorating commuter rail service by establishing the Urban Mass Transit Administration (UMTA). As a predecessor to the Federal Transit Administration, the UMTA began providing capital grants for metropolitan areas with a comprehensive transit plan.

The Rail Passenger Service Act of 1970 enabled the federal government to relieve freight rail lines of their common carriage responsibilities, allowing these companies to end their intercity passenger services. When these passenger rail carriers relinquished their passenger services to Amtrak, many commuter rail services were discontinued. Conrail began privately operating some of these



Drivers and bicycle riders wait for a Massachusetts Bay Transportation Authority Commuter Rail train to pass in Concord, Massachusetts, in 2010. Between 1997 and 2007, U.S. national commuter rail ridership increased 28 percent.

commuter systems until the early 1980s, when the company was on the verge of bankruptcy. As part of the Northeast Rail Service Act of 1981 (NERSA), Conrail was released from its commuter rail carrier obligations, which allowed the five Conrail regional commuter rail systems to be purchased by state and municipal public transit agencies in 1983 and 1984.

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See Also: Commuter Rail Systems; Consolidated Rail Corporation; Federal Transit Administration; Rail Corridor Congestion; Rail Transit Planning, U.S.

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Commuter Rail Systems

Commuter trains are a type of passenger rail intended to be used daily as part of individuals' daily commute. Commuter trains are set apart from long-range passenger rail in that they provide service between city centers and commuter residential areas. In the United States, both commuter and long-range passenger rail share rail space with freight trains; prominent American rail systems include the New York subway system; San Francisco's Bay Area Rapid Transit (BART), Washington D.C.'s Metro, and the Chicago "El" train.

International commuter rail systems include the London tube system; the iZBAN in Ismir, Turkey; and the S-Bahn in the Ruhr region of Germany.

Commuter rail development is by no means uniformly developed around the globe. Asia boasts some of the most advanced commuter rail systems, with notable networks found in India and Japan. European systems, while not necessarily as technologically advanced as their Asian counterparts, are impressive in their accessibility, with most major metropolitan areas served by some sort of commuter rail. Compared to global counterparts, commuter rail lines are limited in North America and South America, with even more limited options in Africa.

Commuter Rail in the United States

Due to historical factors and business interests, freight trains are given priority on American rail lines, with both long-range and commuter passenger trains taking secondary priority. The fact that commuter trains play a vital role in the daily lives of millions of Americans have led many to question if the American commuter rail system is in need of an overhaul. Such expansion raises at least three key questions. First, can commuter rail systems provide an environmentally sustainable alternative to automotive commuter systems? Second, would commuter rail systems alleviate congestion issues experienced in many American cities? Finally, would viable commuter rail systems provide sufficiently appealing alternatives to justify the capital expenditure necessary to put them in place?

Only 6 percent of the 380 metropolitan areas in the United States host functioning rail systems—a total of 24 functioning rail systems nationwide. The largest and most developed rail system in the United States exists in the Northeast Megalopolis (including the Boston, New York City, Philadelphia, and Washington, D.C., metropolitan areas); two-thirds of U.S. rail commuters live in New York City.

The rail systems that occupy the Northeast Megalopolis are connected by the National Passenger Railroad Corporation, known as Amtrak; however, a minority of Amtrak's activity focuses on longer distance travel. Amtrak operates on 21,000 route miles in 46 states, the District of Columbia, and three Canadian provinces. Of those 21,000 route miles, only 363 miles reside in the Northeast Corridor between Boston and Washington, D.C.

As mentioned above, the historic factors that limited rail systems in the United States largely contained those systems to the northeast.

However, the west is not completely without rail systems. The most prominent of those Pacific Coast rail systems is the Bay Area Rapid Transit (BART) system. The first track of this system was laid in 1946; its initial development was driven largely by postwar migration to the area and a corresponding lack of motorways in the area. In fact, counter to the anti-rail trend in the rest of the country, BART was actually developed in order to avoid total dependence on automobiles.

Potential Solutions Provided

Many argue that the implementation of commuter rail systems where they do not yet exist could be greatly beneficial. One such benefit would be more environmentally friendly transportation for America's commuters. Currently, most rail systems in the United States draw their power from the same sources as residential areas; thus they are largely reliant on coal and other fossil fuels. However, once the electrical infrastructure is converted to more sustainable energy sources (such as solar, wind, hydrothermal, etc.), rail systems will likely utilize cleaner energy sources. Additionally, expanded rail systems will allow commuters to give up driving if they wish. If enough commuters transition from their automotive commute to a rail commute, automobile emissions could be reduced significantly.

The argument has also been made that the commuter infrastructure of our nation's cities must be improved to cope with increasingly populated cities. Cities with large populations and limited public transit systems, such as Los Angeles, are already suffering from almost intolerable levels of automotive gridlock. Social scientists are already predicting that the urban sprawl of the last few decades may be receding to be replaced with more centralized, compact cities. Such cities would not be conducive to universal automobile ownership and thus likely would require advanced commuter rail systems.

As appealing as improvements to our rail infrastructure may seem, economic viability will be a major consideration in determining if each given project goes forward. Opponents of rail projects have argued that they are simply too expensive a venture and that the risk is too great that the commuting public will not embrace rail systems. It is not uncommon for states or cities to own rail systems, and most private rail companies receive

some sort of subsidy from the government. For this reason, expansion projects often become embroiled not only in logistical delays but also in political disputes.

Where Now?

There are currently over 25 rail projects proposed or under construction in metro areas across the United States. These include both the expansion of existing systems and the installation of entirely new rail systems. These projects are taking place in Pittsburgh, Austin, Detroit, Milwaukee, and San Francisco, among other cities. If this generation of commuter rail projects moves forward as predicted, we shall see whether environmental and commuting problems if these metro areas are resolved, and whether these cities prosper financially as a result. If so, we may yet see widespread commuter rail in the United States.

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See Also: Alternative Fuels; Environmental Impacts; Railroad Industry, Economics of; Traffic Congestion; Urban Sprawl Versus Compact Development.

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Commuting

Daily commuting, the movement between place of residence and place of work, is a common phenomenon in the modern-day world since the arrival of motorized transportation (electric streetcar, rail,

car, etc.) in late 19th century. Before this time most workers lived less than a 30-minute walk from their work. Approximately 128.3 million U.S. workers (93 percent) commute to work every day and spend on average more time commuting than on vacation each year.

Even though the share of daily travel composed of commute trips has been in decline since 1995, this is not the result of diminishing work travel. Rather, it is due to the dramatic growth of trips in other non-work-related activities. Commuting constitutes less than 20 percent of all trips taken daily, but it is a vital activity for millions of American households during rush hours in the morning and evening and hence plays a unique role in the American transportation system and society.

Unlike many other important American social issues, commuting often dominates public discussion about transportation because it takes place during the most congested times of the day and is experienced by millions of American workers of all income levels, either directly or indirectly. These experiences can be referred to as time and money wasted and boredom with the journey, congestion and mobility, energy and pollution, and so forth, all with negative outcomes for communities, along with less time for family life, stress, and other personal health issues.

According to a Texas Transportation Institute mobility report in 2011, American commuters spent an extra 38 hours traveling, up from 16 hours in 1982, and wasted 19 gallons of fuel—a week's worth of fuel for the average U.S. driver—up from 8 gallons in 1982.

Table 1 Average commute times in the United States and Europe

Country	Average Commute Time
United States	26 minutes
Italy	23 minutes
Spain	33 minutes
France	36 minutes
European Union average	38 minutes
Netherlands	43 minutes
Germany	44 minutes
United Kingdom	45 minutes

Sources: ACS, 2009 and OECD Family Database, 2007.

U.S. Commuting

Americans are spending more time commuting than they did 40 years ago. Based on the 2006–10 American Community Survey, the average one-way commute time was 21.7 minutes in 1980, the first time the census collected commute data. Since then, average one-way commute time increased from 22.4 minutes in 1990 to 25.5 minutes in 2000, and declined only slightly to 25.1 minutes in 2009. Today the average American commutes a little less than 26 minutes and 16 miles each way.

Compared to many European countries, average commutes for U.S. workers are shorter (see Table 1) because of the dominant use of the private automobile for travel. The average travel time for workers who commute by public transportation is higher than that of workers who use other modes. However, the share of “long commuters,” those who commute 60 minutes or longer each way, is on the rise. In 2011, 10.8 million or 8.1 percent of U.S. workers were long commuters, up from 8 percent in 2000. Of all long commuters, “extreme commuters” who commute 90 minutes or more to work each way are also on the rise.

The U.S. 2000 census identified 2.8 percent of commuters as extreme commuters, which is up from 1.5 percent extreme commuters in 1990. However, this proportion has fluctuated since then, and it reached 2.5 percent in 2011. The recent census also classified 3.3 million (3.15 percent) U.S. workers as “stretch commuters” or “long-distance commuters,” who commute 50 miles each way; and 600,000 U.S. workers (0.82 percent) as “mega-commuters,” traveling 90 minutes or more and at least 50 miles to work each way. Moreover, the number of people who start a commuting trip very early (5 A.M. to 6 A.M.) to avoid traffic jams on highways that typically occur during peak commuting hours (6 A.M.–10 A.M.) rose significantly from 6.4 percent in 1990 to 7.6 percent in 2000 and up to 8.6 percent in 2009.

The car is by far the most commonly used mode of transportation for commuting to work in the United States compared to Europe and Japan and other east Asian countries (see Table 2). In addition, American commuters also prefer driving solo to work. Based on the 2006–10 American Community Survey, the majority of American commuters, about 76.1 percent, usually get to their employment locations by driving alone, compared to 64.4 percent in 1980 and 60.0 percent in 1960.

Changes in family structure, such as dual-earner versus traditional households, and vehicle availability primarily affected mode choices since the 1980s. Only 12.2 percent of American commuters carpooled, a decline from 19.7 percent in 1980 but steady since 2000. In contrast, a small percentage of American commuters (5 percent) use public transit for commuting purpose compared to 49 percent in Europe and 56.4 percent in Japan (see Table 2). However, public transit use for commuting is on the rise in the United States after decades of decline.

Europeans are by far more likely to walk to work compared to any other region. Only 3.3 percent of American commuters walked, but this number is rising slowly after decades of decline. Even though bike commuters represent only a small share of commuters in United States, about 0.4 percent compared to Japan and Europe, their number has been steadily rising since 2000.

Sociodemographic Characteristics

Women have significantly different commute patterns than men. Women, for example, tend to have shorter commutes than men but tend to link with other trips. The average one-way commute time for men is 35 minutes versus 20 minutes for women. More than 50 percent of females in the United States commute less than 20 minutes compared to 43 percent of men. In contrast, 9 percent of males are “long commuters” versus 6 percent of females. Similarly, megacommuters are more likely to be older, married, make a higher salary, and have a spouse who does not work. Of the total mega-commuters, 75.4 percent were male and 24.6 percent were women. Mega-commuters were also more likely to depart for work before 6 A.M. Metro areas

with large populations tend to attract large flows of mega-commuters.

Racial and ethnic variation in commuting time and mode choices is also significant in the United States. The non-Hispanic white population has the highest share of less than 20 minutes (48 percent) and the lowest share (7.3 percent) of 60 minutes or above commutes. In contrast, African American (10.62 percent) and Asian populations (10.29 percent) have the highest share of 60 minutes or above commute and the lowest share of less than 20 minute commutes (38.95 percent and 38.58 percent, respectively). By far, more white workers (84.5 percent) drove alone to work than any other racial or ethnic group. The percentage of Hispanic and non-Hispanic Asian workers who drove to work alone did not exceed 70 percent. Notably, Hispanic workers had the highest rate of carpooling to work (16.4 percent). Non-Hispanic Black workers had the highest proportion (11.5 percent) of transit use for commuting in contrast to only 3.2 percent of non-Hispanic white workers.

Similarly, there are significant variations in commute time and mode choice among native-born and foreign-born populations. Commute time is by far longer, with 28.1 minutes for foreign-born workers, compared with 24.9 minutes for native-born workers. Hispanic workers had the longest mean travel time when carpooling (29 minutes) and the shortest time for public transportation usage (46 minutes). Public transit and carpool users also double among the foreign-born population compared to the native-born population (10.8 percent compared to 4.1 percent, respectively). The biggest gap is in bus usage. Black commuters spend an extra 66 hours a year waiting, riding, and transferring than white bus riders.

Table 2 Mode of transportation used for commuting

Region	Mode of Transportation (percent of commuters)			
	Car	Transit	Walk	Bicycle
United States	86.1	5.0	3.3	.4
Europe	26.7	48.7	15.0	5.9
Japan	16.8	56.4	6.8	13.4
Other East Asian	14.6	68.9	10.1	.8

Sources: ACS, 2009 and Japan-guide.com.

Increasing Commutes

The topic of lengthening commutes has naturally attracted attention across the disciplines that deal with its effect on human aspects of everyday life. Among researchers on this topic, geographers, planners, transport engineers, economist, sociologists, and psychologists are recognizable. They have identified a number of reasons for the lengthening commute in the United States:

Suburbanization and low-density development is conducive to a long commute due to job–housing imbalance/mismatch. Job–housing imbalance occurs when the number of workers who can be housed in an area differs substantially from the number of jobs there. Job–housing mismatch occurs when price or other characteristics of the housing in an area are unsuitable (either too expensive or lower quality neighborhoods) for the earning potential of available jobs. Researchers have argued that lack of affordable housing near job locations and racial discrimination and other exclusionary practices in suburban locations have displaced workers to residential communities far from their jobs.

Changes in workforce: A majority of American households are now dual earner, compared to the 1960s. Location decisions for dual-earner households are complex, and the job–housing balance is unattainable for them since living near one household member’s job may mean living far from the other’s. Therefore, it has been suggested that continuing growth of dual-earner families could be an increasingly important factor in increasing commuting time in metropolitan areas.

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See Also: Commuter Paradox; Jobs–Housing Balance/Spatial Mismatch; Reverse Commuting; Travel Patterns by Income; Travel Patterns by Race/Ethnicity; Travel Patterns of the Elderly; Travel Patterns of Women.

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Complete Streets

For more than half a century, the personal automobile has been king of the road in terms of transportation planning and funding in the United States. More recently, consideration has been given to the need to accommodate all modes of transportation, not just the motor vehicle. By designing and retrofitting streets, the complete streets movement takes into account the needs of all users. This thinking represents a trend away from equating transportation with mobility and toward accessibility. Mobility means fast, convenient travel. Accessibility focuses on the ability to reach desired destinations safely.

By according consideration to pedestrians, bicyclists, and users of public transit, a complete street is one that may include wide sidewalks, bike lanes, bus lanes, and a variety of traffic-calming devices such as raised crosswalks and pedestrian signals, as well as other features that demonstrate concern for the nonmotorist. The complete streets movement upends the prevailing thought by first considering the most vulnerable of users, the pedestrian. Bicyclists and mass transit users are then accommodated, only after which is automobile mobility

addressed. Ultimately, the complete streets ideal is to provide transportation options that may ultimately transform the community at large.

Though a relatively nascent movement, complete streets policies have already been adopted or received commitment to do so by more than 200 jurisdictions nationwide, including statewide laws or ordinances in 15 states. The foundation of the movement is frequently traced to the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA), which dramatically increased the amount of federal funding available for pedestrian and bicycle facilities.

In 1998, the Transportation Equity Act for the 21st Century (TEA-21) further augmented federal funds for nonmotorized spending. By 2003, more than \$1.4 billion was spent on bicycle/pedestrian projects under TEA-21 funding. The most recent federal transportation legislation, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was

enacted in 2005 and afforded an even more dramatic upsurge in potential federal funding on bicycling and walking. Set to expire in 2009, SAFETEA-LU was extended through 2012 and has been recommended by the U.S. secretary of transportation to receive additional funding by Congress in 2013.

Determination of how best to allocate the funds is left to metropolitan planning organizations (MPOs) in metropolitan areas with populations greater than 50,000, and by state departments of transportation (DOTs) for smaller metro areas and nonmetro areas. As Congress has not mandated that the money be spent on bicycle or pedestrian infrastructure, there may be considerable variation in how transportation funds are allocated.

Despite this variation, nonmotorized transportation options have received augmented funding due to growing awareness of the many tangible benefits of complete streets. Increased safety, improved health, and reduced traffic congestion, as well as increased social capital, economic opportunity,



This Vancouver, Canada, street design incorporates a physically separated two-way bike lane and wide sidewalks, allowing a large number of people to use of modes of travel besides automobiles. Improvements in bicycling, walking, and mass transit facilities as promoted by the complete streets movement can improve neighborhood quality of life as well as reduce fuel consumption and waste. It is estimated that increasing U.S. bicycle trips to 1.5 percent, up from 1 percent, could save 500 millions gallons of gasoline a year.

land values, and overall livability, are all linked to complete streets. The National Household Transportation Survey has found that fully half of all trips that occur in the United States are 3 miles or less. With options of multimodal travel, these trips may readily and even preferably be made via walking, bicycle, or mass transit.

In settings with incomplete streets, the automobile remains the primary mode of travel due to safety issues or a lack of alternatives. Complete street communities can help reduce automobile travel and increase movement via other options. Small changes, made collectively in communities throughout the United States, can net a profound impact. As noted by Dan Burden and Todd Litman, merely increasing trips made by bicycle from 1 percent to 1.5 percent of all trips in the United States would save nearly 500 million gallons of gasoline per year. Similarly, current use of mass transit is already helping save just under 4 million gallons of gasoline every day.

Fewer motor vehicle trips not only lessen gasoline consumption and dependence on oil, but also lead to cleaner air by reducing greenhouse gas emissions. Complete streets also bring social and economic benefits to communities. Work to develop new infrastructure or upgrade existing streets is part of every community's yearly budget. This work, which would necessarily have taken place anyway, can be designed to follow the complete streets model. The creation of complete streets is therefore not truly a new or added expense. On the contrary, fewer cars on the road means infrastructure savings, while improvements in walking, bicycling, and mass transit facilities can contribute to increased tourism, retail sales, and land values. Moreover, complete streets add to the more intangible concept of livability. Feelings of safety, environmental quality, social equity, and economic opportunity all contribute to a sense of place and quality of life that benefit from the complete streets model. People who are given an opportunity to walk are more likely to meet recommended physical activity levels as well as to improve their social connections and enjoy a heightened sense of neighborliness. As a result, complete streets are about much more than just infrastructure.

Despite the unquestioned benefits of complete streets, the movement can experience obstacles in implementation. Transportation policies in many

communities still favor mobility over accessibility, while a lack of integration can limit the success of complete streets. Widening a sidewalk or adding a bicycle lane is insufficient. Rather, the complete streets efforts must be tied to larger land use and transportation planning efforts.

The National Complete Streets Coalition has identified 10 essential elements of an ideal comprehensive complete streets policy as one that includes a vision for how and why the community wants complete streets; specifies that "all users" includes pedestrians, bicyclists, transit users, and motorists of all ages and abilities; encourages streets to be connected; is adoptable by all relevant agencies to include all roads; applies to new, maintenance, and resurfacing projects; clearly explains any exceptions; directs the use of the latest design standards while also recognizing the need for flexibility; focuses on the positive community impact as a result of complete streets; establishes performance standards with measurable outcomes; and includes specific next steps for implementing the policy. This 10-step program, in tandem with community support and incorporation into relevant land use and transportation policies, offers a blueprint for successful complete streets development and implementation.

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See Also: Accessibility and Mobility; Bikeways/Bike Lanes, Road Design Issues of; Intermodal Surface Transportation Efficiency Act; Liveable Streets; Neotraditional Neighborhoods and Transportation Impacts; Nonmotorized Transportation; Pedestrian-Friendly Design; Sustainable Transportation; Traffic Calming; Transportation Equity Act for the Twenty-First Century; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users.

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Congestion Mitigation and Air Quality Program

The Congestion Mitigation and Air Quality Improvement (CMAQ) Program is landmark legislation passed in the first months of the Clinton Administration as part of its commitment to assist metropolitan areas that were routinely subjected to air quality warnings due to poorly-managed high-volume traffic congestion.

It remains the first and only federally funded program aimed specifically at addressing air quality through surface transportation improvements. The program was part of the Clinton Administration's overall vision of responsible, cost-effective environmental policy that could go hand in hand with economic development.

Congestion mitigation has long been a critical element in transportation planning. Indeed, the evolution of the American nation was tied to surface transportation management. Unprecedented development over the past century and half of an increasingly sophisticated network of surface transportation systems has been intrinsic not only to uniting the country and building a national economy but also to sustaining the spirit of mobility that has become an essential element of a restless nation proud of its pioneering spirit.

Surface transportation evolved within decades from hastily fashioned trails west and south to a system of maintained roadways, then to the introduction of a massive system of rail lines. Within a generation came the automobile, streets and highways, and an increasingly complex system of interstate freeways. Thus, congestion mitigation has long factored in transportation planning.

Unlike other urban and industrial development—such as housing or building construction—transportation systems have more widespread and longer lasting impacts on their environments. Roads and highways are around for generations. It is far easier, after all, to raze a factory and replace it with one more efficient than it is to remove an entire highway system. However, in the 1970s environmental scientists, climatologists, and mechanical engineers first began gathering hard data on ambient air quality and the growing problem of air pollution from fossil fuel vehicles—even as the number of those vehicles skyrocketed.

From the beginning, the goal in the government's endeavor to manage vehicular congestion was both practical and pragmatic. With the cooperation of congressional oversight committees, blue-ribbon committees made up of academics and field specialists, as well as federal agencies responsible for transportation and highway maintenance, the emerging policy focused on developing realistic, short-term goals that would have immediate and measurable impacts on air pollution, particularly in urban areas that consistently failed to attain federal minimum air quality standards.

By the early 1990s, in the closing months of the first Bush administration, principal goals had been outlined to reduce congestion and improve air quality: (1) reduce fossil fuel emissions, (2) encourage multipassenger and/or public transportation systems to reduce traffic volume, (3) step up vehicle inspection and maintenance, and (4) develop workable alternatives to vehicular transportation, most notably bicycling and pedestrian programs.

The sweeping Clean Air Act Amendments (CAAA) passed by Congress in 1990 had begun to tackle the problem of urban air pollution by imposing hard deadlines for cities to meet nationally set air quality standards. So-called nonattainment areas were most often in large cities with sprawling highway systems built during the 1950s and 1960s and, therefore, not up to the high capacity demands of late 20th-century traffic. Determined to bring those zones into compliance, the Federal Highway Administration, the Federal Transportation Administration, and the Environmental Protection Agency considered stringent compliance requirements the best way to mitigate urban traffic congestion. Within a year of the passage of the CAA amendments, Congress established the CMAQ program to fund project proposals for initiatives that addressed surface transportation problems.

Its passage attracted little national attention, yet it has become something of a model for how the federal government can actually work effectively through small and targeted government initiatives producing measurable and specific results. Initially, the program was given a six-year charter and a \$6 billion dollar budget. One of the long-standing problems that the new program was designed to eliminate was simply the unworkable centralized nature of so much urban traffic planning, which too often exacerbated rather than relieved clogged

traffic conditions. Often local agencies simply lacked the broad-based funding necessary to seriously tackle vehicular congestion. By placing the evaluation of potential programs in the hands of a complex of federal agencies, the CMAQ program sought to encourage immediate, practical, and workable solutions to local problems.

The program met with great success and was reauthorized in 1998 under the Transportation Equity Act for the Twenty-First Century (TEA-21); its budget was increased to \$8 billion. Despite the changeover to a Republican administration and despite the general reduction in federal spending and the economic downturn in the aftermath of the September 11, 2001, terrorist attacks, the program was again reauthorized in 2005 as part of the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU); and, under the Obama administration, most recently in July 2012, in the Moving Ahead for Progress in the Twenty-First Century Act (MAP-21).

The high degree of bipartisan support indicates both the level of the federal commitment to bringing areas into air quality compliance and the sense of urgency surrounding the potential consequences of climate change. It is difficult to overestimate the achievement of the CMAQ program—to date, through both Republican and Democratic administrations, through economic boom times and economic downturns, it has funded more than 29,000 transportation/environmental projects for more than 23 states and has overseen the distribution of more than \$30 billion.

Under the program, proposals may be submitted by local governments, state governments, public transit authorities, public transportation management administrations, and even public and private corporations, according to an elaborate formula that takes into account three critical factors: population density, ozone and carbon monoxide measurements as well as particulate matter, and most important, vehicle distribution and concentration.

Evaluating the worth of project submissions and deciding on what projects receive funding must take into consideration a number of interrelated concerns, including transportation demand analysis, long-term urban planning, air quality monitoring, human exposure assessment, population demographics, emissions regulations, vehicle engineering, fossil fuel supplies and distribution,

ecological balance, the viability of the industrial superstructure, local environmental planning, short- and long-term economic development initiatives, as well as the complex interplay between local and state politics.

The broad intention of congestion mitigation is to decrease travel demand and the volume of traffic on urban surface transportation systems and at the same time encourage more efficient use of existing roads, targeting specifically those conditions that routinely create stop-and-start traffic (idling is a particular concern in air quality) or in some cases shut down entirely the flow of vehicular traffic as in the case of accidents, large-scale events (such as sporting events or concerts), or inclement weather.

Because the CMAQ program has been one of the most successful (and, ironically, least publicized) government environmental initiatives of the past generation, and because of the sheer reach of its sponsored programs, it is difficult to list comprehensively the projects funded under its aegis. The program invites projects that expand existing programs or systems or introduce cutting-edge initiatives and/or propose pilot programs. Tradition and innovation thus have become hallmarks of the federal government's response to congestion mitigation.

Certainly the most consistently funded project proposals over the past 20 years center on projects designed to improve existing public transit systems, from infrastructure repairs and renovations to software updates to ensure smoother and more reliable service as a way to attract additional riders. But funded projects have also included encouraging employer-based transportation demand management (TDM) initiatives, such as flexible work schedules for employees, providing incentives for employees who carpool, and reducing the amount of corporate-sponsored travel by encouraging virtual conferencing. In addition, the CMAQ program has funded informational seminars, Internet sites, and weekend retreats to tout these shared-ride projects.

Effective congestion mitigation, however, relies primarily on improving the surface transportation system itself—and consequently much attention, and much funding, has been given to providing parallel highways systems to reduce traffic snarls and limit idling or adding additional lanes to off ramps to cut down on traffic backing up into travel lanes, or renovation and resurfacing projects to

rehabilitate heavy-use roadways. In addition, innovative proposals have been funded to build new shopping plazas, hotel facilities, spacious sports/concerts venues, and even local government complexes outside metropolitan areas as a way to attract vehicular traffic outward rather than inward. Although congestion relief relies on improving traffic flow and minimizing starting and stopping, real impacts in improving air quality rest ultimately in two areas: cutting down on the number of vehicles using the roadways and ensuring that those vehicles are in prime operating condition.

Projects have been funded to construct high occupancy vehicle (HOV) lanes or have provided special access around long-term construction projects to vehicles with multiple occupants. Outdated, boxy buses with traditional seats have been replaced by sleek, comfortable new models with ergonomically appropriate seats, wider aisles, and bigger windows to encourage higher patronage.

The CMAQ program has also addressed the fact that just 10 percent of the cars on the road are responsible for 60 percent of all emissions. Auto Club data indicates that Americans, perhaps leery over continuing economic uncertainties or the apparent random fluctuation of gasoline prices, have begun to hold on to their vehicles longer. Just 25 years ago the average age of a car on America's roadways was seven years; in 2013, that number was almost 12 years. Although many owners have kept up maintenance on their automobiles (and despite the Obama administration's valiant Cash Allowance Rebate Program, the so-called Cash-for-Clunkers initiative), the inevitable result is a massive number of vehicles with aging engines and increased emissions. Thus, the CMAQ program has beefed up emissions inspection programs, updating their software to improve accuracy and efficiency.

Finally, congestion mitigation policy has targeted urban programs designed to make cycling an attractive transportation alternative—enhancing highways with bike lanes, providing security racks for parking bikes, providing basic maintenance stations, encouraging businesses to provide support—and to encourage cities to accommodate pedestrians by providing secure paths, bathroom facilities, and smooth riding surfaces.

In conclusion, successful implementation of congestion mitigation strategies to reduce automobile emissions requires the cooperation of multiple

levels of local and state governments as well as business support and public awareness. These have become the hallmarks of the campaign to improve air quality through congestion mitigation.

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See Also: Air Pollution/Air Quality; Automobile Culture; Automobile Pollution; Surface Transportation Systems.

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Consolidated Rail Corporation

Railroads have long been an integral element in America's transportation history, transporting both passengers and freight throughout the country. However, the post–World War II period was marked by a significant decline in the importance of railroads to the U.S. economy. Acquisitions and mergers were seen as a way of surviving as railroads continued to diminish in importance. By the early 1970s, there were six major railroads serving the northeast and

the midwest: Central Railroad of New Jersey, Erie Lackawanna, Lehigh and Hudson River, Lehigh Valley, Penn Central, and Reading. Beset by falling revenues and unable to keep tracks and equipment in proper repair, these railroads began to fold in the first years of the decade.

With railroads unable to survive on their own, the government stepped in following the passage of the Regional Rail Reorganization Act of 1976 to create the Consolidated Rail Corporation, popularly known as Conrail, out of the remains of Penn Central, which had been formed in 1968 by the merger of Pennsylvania and New York Central Railroads, and five other bankrupt railroads. At the time, Penn Central was responsible for 20 percent of all freight delivered by rail in the United States and for 70 percent of passenger rail service in 16 northeastern and midwestern states. The United States Railway Association was established as a nonprofit government corporation and charged with monitoring Conrail and serving as its banker.

In 1980, passage of the Staggers Rail Act removed most economic restrictions on railroads, allowing them to become more competitive with the trucking industry. The creation of the National Railroad Passenger Corporation (Amtrak) and the transfer of financial responsibilities to states further eased financial burdens for Conrail and other railroad freight carriers. In 1981, a plan was devised to sell Conrail, which had continued to be besieged by poor management, labor problems, and other issues, to private investors. Instead, Conrail was ultimately sold as a public offering.

Early Days

In the 1970s, the survival of freight trains was continuously being threatened by long-haul trucking and airfreighting. By 1973, it was estimated that bankrupt railroads were losing approximately a million dollars a day. Three years later, Conrail was created by the U.S. government after it purchased assets of Penn Central and several other bankrupt railroads for \$3.4 billion.

Upon its creation, an independent board of directors, made up of members appointed by the U.S. Department of Transportation and the United States Railway Association, was charged with establishing policy for Conrail's operations. The initial plan for Conrail had been that it would become an independent entity by 1979. Instead, despite

receiving \$6 billion in federal funds, Conrail was on the verge of total collapse.

In conjunction with deregulation of the airlines and the trucking industry, President Jimmy Carter began pushing for deregulation of the railroads, resulting in the passage of the Staggers Act of 1980, which gave Conrail a good deal of flexibility in setting prices and removed most anti-trust restrictions. Railroad officials contended that government controls had stymied the ability of railroads to actively compete with trucking companies and prevented them from responding to rising inflation. Over the course of 1980, Conrail lost some \$244 million, and nine railroad carriers declared bankruptcy. The lack of maintenance funding meant that tracks and equipment were often in poor repair.

Up for Sale

By 1981, Conrail was regularly traveling 17,000 miles of track, delivering goods in 17 states. That same year, Secretary of Transportation Drew Lewis estimated that Conrail would require some \$4 billion in additional subsidies over the next four years in order to stay afloat. In response, President Ronald Reagan submitted a plan to Congress that called for selling Conrail piecemeal.

Subsequently, 15,000 rail workers marched on Washington. Congress rejected Reagan's proposal, choosing instead to approve a plan that would ensure Conrail's survival by making it self-sufficient and preparing it for eventual sale and rebirth while keeping it intact.

In July 1981, as part of the Omnibus Budget Reconciliation Act, Congress established a timetable for the eventual sale of Conrail. In order to keep it afloat in the interim, Congress authorized \$262 million for operating costs and provided another \$400 million for labor protection expenses. All passenger services in New York, Connecticut, Maryland, New Jersey, Massachusetts, and southeastern Pennsylvania were transferred to Amtrak, the government-subsidized passenger rail service.

One of Conrail's first priorities was to cut labor costs. Since 1973, Conrail had been required to pay approximately 11,000 employees stipends of between \$500 and \$1,800 a month until they reached the age of 65 as a result of agreements reached with railroad employees when Conrail had been created. Under the new guidelines, nonunion wages and

benefits were cut, and new procedures for collective bargaining were instituted. The revamping of Conrail's employee benefits was met with skepticism and threats of strikes.

By the end of 1981, Conrail was succeeding in returning a profit for the first time in its history, and plans for its sale proceeded. By that time, Conrail had received government funding of \$7.6 billion. The top three bids were from the Alleghany Corporation, J. Willard Marriott, Jr., and the Norfolk Southern Corporation. Critics of selling Conrail to a private corporation generally focused on the negative impact of job losses, cuts in freight service, potential exploitation, and lack of confidence in Conrail's ability to succeed without government help.

Many members of Congress were also afraid of problems that could ensue in the case of a resale outside congressional control. In June 1981, federal subsidies to Conrail ended. Under the guidance of Chief Executive Officer Stanley Crane, Conrail's profits had climbed to some \$500 million by 1984. Crane had achieved the turnaround in large part by cutting labor costs in half and reducing mileage by one-fourth.

Sold!

Ultimately, the decision was made to sell the 85 percent of Conrail owned by the U.S. government as a public offering. With more than 18 million shares up for sale, the Conrail stock was the largest public offering in U.S. history. On March 26, 1987, the government netted some \$1.9 billion from the sale combined with cash payments from Conrail. With that move, Conrail became a private entity. In 1997, Conrail was acquired by Norfolk Southern Corporation and CSX Corporation, with each corporation becoming responsible for one-half of Conrail's services, effective June 1999.

Thirty years after the passage of the Staggers Rail Act, both scholars and government and railroad officials were virtually unanimous in their praise for the deregulation of the railroad industry, which had allowed Conrail to succeed financially and paved the way for its eventual sale. That action is now considered one of the major successes of President Jimmy Carter's administration.

Due to financial solvency, railroads reinvested some \$511 million in capital improvements between 1981 and 2009. According to the Department of Transportation, the accident rate for that

same period declined by 65 percent as a result of those improvements.

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See Also: Deregulation; National Railroad Passenger Corporation/Amtrak; Railroad Industry, Economics of; Railroads, Freight; Railroads, Passenger.

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Construction Management

Planning, design, construction, and operation of surface transportation infrastructure projects—primarily highways and transit facilities—have traditionally been funded and managed by public-sector transportation agencies. Since the establishment of the Highway Trust Fund (HTF) in 1956, funding for highways and, later, other surface transportation facilities has derived chiefly from automotive fuel taxes gathered at the state level, remitted to the federal government, and distributed to the states in proportion to their respective contributions.

While sufficient for many years, recent improvements in vehicle fuel economy and reductions in



Construction underway in 2013 on the Innerbelt Bridge project in Cleveland, Ohio, where the interstate highway crosses over the Cuyahoga River. The state project has been accelerated by using a design-build-finance (DBF) approach with a private-sector partner. The DBF approach means that the private-sector partner partially or totally funds the project development using its own capital, or it arranges for short-term financing in anticipation of being paid in full by the public sector at a later date.

total vehicle miles traveled have reduced these fuel tax revenues to the point where the HTF has begun to run a deficit that has required general fund contributions to meet state funding obligations. This comes at a critical time when the interstate system and other components of the U.S. surface transportation infrastructure (for example, state highways and bridges) are approaching the ends of their design lifetimes and are in need of significant repair or replacement.

In response to these pressures, the role of the private sector in public surface transportation facility development expanded in the 1990s with the passage of the Intermodal Surface Transportation Efficiency Act of 1991. The federal government has been experimenting with alternatives to the traditional public-sector-driven approach to the creation and maintenance of surface transportation facilities

in the United States. These approaches focus not only on creative financing vehicles for transportation facilities (for example, the Transportation Infrastructure Financing Innovation Act, TIFIA) but also on the closer engagement of the private sector in all phases of the project life cycle. These public-private partnerships (PPPs) are designed to leverage private-sector innovation, capital, and capacity to design and implement surface transportation projects that might not be achievable or affordable in a timely fashion if left to traditional public-sector transportation programming.

According to its proponents, a public-private partnership capitalizes on traditional strengths of the private sector—innovation, cutting-edge technology, and access to private capital and labor markets among them. In this view, the private sector is often better positioned to build, if not finance,

operate, and maintain the country's surface transportation infrastructure. Critics argue that ceding these responsibilities to the private sector reduces the degree of accountability to the voter for these transportation services and may result in the neglect of legitimate geographical transportation or social needs to the benefit of market priorities.

In its PPP programs, the U.S. Department of Transportation distinguishes between new and existing facilities and recognizes a gradient in the levels of public-private participation among the various partnerships. From more to less public responsibility for new facilities: Private Contract Fee Services, Design-Build, Design-Build-Operate-Maintain, Design-Build-Finance, Design-Build-Finance-Operate-Maintain, and Build-Own-Operate. For existing facilities, two PPP frameworks are examined: Operate & Maintain Concession and Long-Term Lease Concession.

Private Contract Fee Services

While retaining ownership and ultimate responsibility for their transportation facilities, public-sector agencies often outsource project management responsibilities to private-sector firms to capitalize on the latter's expertise and capacity to accelerate the implementation of transportation projects. In addition to facility construction projects, state agencies may also rely on the private sector for financial management and capital investment services. Examples of projects typically contracted to private-sector firms include highway construction and widening, and bridge construction or replacement.

An example of the benefits of this type of arrangement was the \$5.3 billion South Carolina "27 in 7" effort, which resulted in the completion in seven years of over 200 surface transportation projects originally scheduled to require over a quarter century to complete. The largest initiative of its kind, it employed financial incentives and disincentives to streamline strategic planning and financial management and coordinate design and construction activities.

Design-Build

Usually addressed in separate contractual agreements, a design-build arrangement combines architectural/engineering services and construction into a single fixed-fee contract between the transportation agency and one or more private-sector firms.

The public sector retains responsibility for securing project financing, initial planning, and facility operations, maintenance, and ownership.

A 2006 assessment of design-build project effectiveness concluded that some of the largest advantages of this public-private arrangement came in the timeliness of project execution and in cost savings realized by private-sector innovation and the less adversarial relationship established between public and private sectors in the process of project management. The four-segment, 91-mile-long SH 130 component of the Central Texas Turnpike System was approved in 2001 and completed in 2007. Because of the design-build public-private partnership, the facility was delivered under budget and 25 years sooner than would have been possible under traditional contractual arrangements.

Design-Build-Operate-Maintain

A further consolidation of transportation facility life cycle responsibility is achieved by combining into a single contractual agreement responsibility not only for the design-build portions of the project but also for long-term facility operations and/or maintenance. The public sector retains responsibility for arranging the financing of the project.

Significant benefits attributable to the design-build-operate-maintain (DBOM) arrangement are recognized through an increased focus on the facility's entire life cycle, which enables the contracting entity to reduce project costs that accrue over the productive life of a transportation facility. As opposed to contractual and operational inefficiencies inherent in sequential design-build and operate and/or maintain contracts, a single contracting entity can design and construct the transportation facility with long-term operational and/or maintenance efficiencies in mind. The initial 9.5-mile phase of the three-phase, 24-station Hudson-Bergen Light Rail transit system, completed in 2000, was the first DBOM selected in the United States. Because of the efficiencies realized in this public-private partnership, this phase was estimated to have been delivered eight years sooner than would have been possible through the traditional multiple design/bid/award/construct approach.

Design-Build-Finance

When a public-sector project sponsor finds itself in a cash flow-constrained position or merely wishes

to defer payment for facility development services, it may elect to rely on the financial capacity of its private-sector design-build partner. In the design-build-finance (DBF) approach, the private-sector partner partially or totally funds project development by either using its own capital or arranging for short-term financing in anticipation of full public-sector repayment in the longer term. This arrangement involves the transfer of an enhanced degree of financial risk to the private sector associated with the uncertainty of the public agency's future project funding capacity as a function of state or federal appropriations.

An example of the DBF approach is the Innerbelt Bridge currently being constructed over the Cuyahoga River into Cleveland. The westbound lanes were constructed using a design-build arrangement between the Ohio Department of Transportation (ODOT) and the private sector. Because of a gap in available funding, ODOT is using a DBF approach to accelerate by three years the construction of the eastbound lanes.

Design-Build-Finance-Operate-Maintain

An extension of the DBF approach, design-build-finance-operate-maintain (DBFOM) is used to achieve fiscal and operational efficiencies across the entirety of the facility life cycle. In contrast to the short-term financing characteristics of the DBF approach, DBFOM arrangements are financed by long-term debt secured by future facility-generated revenue, most commonly user tolls, for the contractually specified duration of the concession. Project sponsors also find DBFOM arrangements attractive because they often provide access to new sources of equity and financing.

Two general categories of DBFOM frameworks are used in the United States. "Real toll DBFOM concessions" leverage facility toll (or other concession) revenue streams as sources for debt retirement and return on investment (ROI), though some public-sector funding contributions may be necessary. As a result, the private-sector concessionaires assume the risk that these operational revenue streams may not entirely meet their debt obligations and ROI forecasts. The Dulles Greenway in Loudon County in northern Virginia is a tolled facility that was privately financed and built and is operated by a private-sector partnership. Facility toll revenues secure the construction debt.

Facility financing risk is retained by the public sector in "availability payment DBFOM concessions." In this approach to facility development the project sponsor commits to a schedule of payments predicated on project delivery milestones and/or operations performance standards (for example, lane closure frequency and incident management) over the lifetime of the concession. This arrangement may be selected when the facility is toll-free or is not expected to generate a toll revenue stream sufficient to service the project debt. The Denver Metro Area Eagle Project includes 122 miles of commuter rail and light rail, 18 miles of bus rapid transit service, and other facility renovations and improvements. While the Regional Transportation District will retain ownership and all revenues from the project facilities, the private consortium Denver Transit Partners was awarded a 34-year DBFOM concession under which it will receive regular payments based on established performance metrics.

Build-Own-Operate/Build-Own-Operate-Transfer

At the far end of the continuum of public/private spectrum lies build-own-operate (BOO) and build-own-operate-transfer (BOOT), also known as build-operate-transfer (BOT). In these arrangements the project sponsor cedes to its private-sector partner(s) responsibility for design, financing, construction, maintenance, and operation for the duration of the concession. The ownership of the facility may be granted to the private consortium only for the duration of the concession (BOT) or in perpetuity (BOO). In the latter case (BOO), transportation projects are more likely than in other arrangements to be originally conceived by the private sector.

Operate and Maintain Concession

In an attempt to realize management, service, and/or technological efficiencies, an existing public facility owner may grant an operate and maintain (O&M) concession to one or more private partners in return for fixed-fee or performance-based payments. Services often provided under these arrangements include ongoing activities such as grass mowing and snow removal as well as facility maintenance and repair.

An O&M concession is often part of a public-sector strategic asset management approach that

attempts to achieve a longer productive facility lifetime through a level of upkeep and repair that cannot normally be provided by the facility owner. An O&M fee service contract was granted by the Alaska Department of Transportation and Public Facilities for the operation and maintenance of the Anton Anderson Memorial Tunnel, the first dual mode rail/vehicular tunnel in the United States.

Long-Term Lease Concession

While an O&M concession is appropriate for surface transportation facilities that do not produce a revenue stream (for example, nontolled highways or bridges), the public-sector financier/owner of a toll facility may grant a lease concession to a private-sector partner for the long-term operation and maintenance (and, sometimes, improvement) of the facility. Instead of being paid in regular or performance-based installments from scheduled or appropriated public funds, the concessionaire derives its cash flow from the tolls charged to users of the facility. A one-time concession fee charged to the private-sector partner may be used to defease the debt accrued by the public sector in the facility's construction. This transfers to the private-partner responsibility for retiring the construction debt using the toll revenue stream.

Built in 1958 and managed by the City of Chicago Department of Streets and Sanitation, a 99-year concession was granted to Cintra/Macquarie, a Spanish/Australian consortium, for the long-term operation and maintenance of the 7.8-mile toll facility. This was the first long-term lease of an existing toll road in the United States.

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See Also: Highway Finance; Highway Trust Fund; Toll Roads, Private.

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Construction Management, Public Relations and

The impact of infrastructure planning and construction on communities is often the subject of media headlines and sometimes legal disputes. As infrastructure plans are designed to improve the quality of life, construction activities initiated by such plans add useful functions that are eventually manifested to the public; yet such construction projects can be disruptive to the community.

The impacts on the community can be classified by type as impacts on individuals and households and as impacts on businesses (local and major chains). The process of identifying and mitigating these impacts calls for community impact assessment as part of an encompassing environmental assessment process.

The front stage of community impact assessment includes the geographic and demographic boundary of the assessment and, more importantly, the community profile. In the context of transportation, the impacts are generally classified under three main categories: availability of services, safety, and possible relocation of residents or businesses.

Public engagement was traditionally portrayed as a mechanism for maintaining a balance of power between citizens and their government in the process of decision making. The main role of this mechanism is to minimize the impacts and risks of failure of decisions made in the construction of transportation systems. Effective public engagement must be a continuous process starting early before the planning and design phases and extending to cover the whole project life cycle (including operation, maintenance, and even, in some cases, decommissioning).

Current Decision-Making Process

Decision making for the construction of transportation infrastructure is a complicated process

involving complex interactions among multiple stakeholders with diverse (and sometimes conflicting) interests. Community members, as the end users of the urban infrastructure services, form one important group of the stakeholders and traditionally participate in the process of decision making as a part of the feedback loop.

The decision-making process usually starts with “problematization,” which includes detection of the issues, identification of the main participants in the process (along with their interests), and realization of the alternatives. Once goals, objectives, and priorities are stated, data is collected and interpreted for preparation of a general plan, along with draft implementation programs. Social, environmental, and economic impacts of the general plan and implication program are assessed and the results are published for the community to offer feedback.

Once the feedback is collected and considered, an edited plan will be issued. The process has a recursive nature and is highly dependent on the decision makers and feedback providers. People who are truly interested and are able to serve on the planning team are suggested as candidates and the community selects a committee to represent it by participating in the meetings where the planning process and expected accomplishments are explained. Meetings with all participants are held regularly to bring them up to date on work and to collect their general feedback as a constructive step toward developing consensus about the plan.

Impacts on Businesses and the Community

The construction of highways and other urban transit services inevitably impacts businesses and communities. Damages to the urban cores and historical sites due to demolition necessary for construction, change in land use, traffic infiltration and intensification, noise, and risk to public safety during and after the construction phase are among other such impacts. The community usually reacts against any project that is perceived not to serve their interests or to jeopardize their safety.

In many cases, social trends may shift and can impact the community’s attitude. The case of the Spadina expressway in Toronto, Canada, is a case in point. It was stopped at the construction phase in early the 1970s under the pressure from a community group, although the project received a supporting vote from the majority of the neighborhood

in the planning phase in the 1950s. Therefore, it is critical to carefully analyze the nature of local communities and plan the community engagement process to ensure the community is truly aware of the impacts, construction schedule, and planned disruptions. Local residents, business owners, and other community representatives, as well as the city staff and planners, should partner as members of one team and actively collaborate on creating solutions to disruptions caused by construction and any concerns that the community brings up. Feedback from the public is absolutely essential in reaching effective solutions to minimize disruptions to the community and businesses during construction.

Community Engagement Process

The evolution of the community engagement process from a “public relations” exercise to a more “engaged partnership” has been highlighted as an objective in recent projects. In the past, community engagement was mostly limited to informing and educating the public with the aim of maintaining public support. The process is now evolving into other forms of consultations that employ two-way communication.

One public participation standard is the International Association for Public Participation (IAP2) spectrum, which proposes that public impact can be enhanced at five levels: informing, consulting, involving, collaborating, and empowering. At the lowest level, static tools such as Web pages and open houses are commonly used with the objective of providing the community with information regarding a specific project or decision impacts.

Most of today’s community engagement activities, however, fall under the consult, involve, or collaborate categories. These are levels at which surveys, polls, public meetings, and citizen advisory boards are common to achieve the higher objectives of partnering with the public in creating alternatives and informing the decision-making process through partnership.

Lately, various visualization techniques have also been acquired to enhance such communication through a better representation of complex concepts (such as changes in the character of the street, neighborhood, or city). In addition, the social web has facilitated a third dimension that includes versatile collaboration between community members for collective deliberation on complex topics. In the

context of infrastructure planning and construction, a major step that follows is how to integrate the impacts and solutions identified in the community engagement process into decision making.

Opportunities for Improvement

Despite the effort put into achieving progress, occasional community dissatisfaction, as portrayed by the media, indicates that the public involvement process may not have achieved all its objectives in some cases. This situation can consequently lead to the failure of the decision-making process as a whole. Several factors can cause such inefficiency. Impact assessments in general and environmental impact assessments (EIAs) in particular have been criticized for failing to achieve a number of their goals. Public anticipation and sometimes frustration due to the length of the assessment, planning, and implementation period is one of these critiques.

On the other hand, the shift of the power in the hierarchy of the decision makers sometimes redefines decision goals along the way in the project life cycle, which can result in the conflict between social norms/values and decision makers' objectives.

Furthermore, the current controlled mechanism of providing the community with predefined alternatives and diminishing their role as alternative generators and solution providers has been linked to a lack of innovative solutions for the development of infrastructure in general, and transportation systems in particular.

To overcome some of these shortcomings in the process of public engagement, a trend has emerged to replace the current "push" mindset in collection of feedback with a "pull" system of detecting demand and collecting feedback by leveraging the public with the tools available in the social web and online social media. Looking at the infrastructure project as a marketable product, some transportation planning agencies approach the process in a manner similar to how marketers engage customers in the field of commerce, and how the reverse marketing mechanisms collect the user innovation.

Last but not least, different phases of a project's life cycle have unique impacts on the community and businesses and must be addressed. Hence, the engagement of the community should not stop at the decision-making stage or once the design is finalized. To the contrary, it must reach beyond construction

to be integrated into the whole project life cycle as a continuous process.

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See Also: Construction Management; Neighborhood Disruption From Highway and Transit Construction and Operations; Public Participation in Transportation Planning.

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Container Terminals

A container terminal is the set of facilities at a port devoted to the loading and unloading of containers through autonomous operations. One or more of these terminals exist in a cargo port that engages in

the transfer of containerized goods and is referred to as a container port.

Container terminals represent a recent perspective of serving maritime transportation. They appeared in the last 40 years because of the increasing use of the standardized box that can hold about 20 tons in weight and can withstand having five full containers stacked on top of it. Before 1970 only the New York Port Authority and the ports of Rotterdam and Singapore had invested in building and operating specialized container terminals.

Today, specialized container terminals are found in all seaports that serve international trade. They lift more than 50 million containers per year around the globe, as over 90 per cent of international non-bulk trade travels in containers, including cargoes that were previously considered not suitable for containerization. Containers handled are either full or empty. The empty ones account for more than 20 percent of the global container port throughput. More than 100 ports handle over 1 million TEUs (20-foot equivalent unit) per year, with two or more container terminals operating in the vast majority of them. Annual throughput in nine ports in Asia and in Rotterdam exceeds 10 million TEUs.

The transshipment (ship-to-ship) concept and the increasing transportation of intermediate goods along supply chains are driving forces for the rise of container handling, the operational restructuring of this handling, and the specialization of container terminals.

The modern container terminal is generally found in one or both of two types of ports. The transshipment hubs are designed to optimize the transfer of containers from one maritime vessel to another between networks of long-distance and/or short-distance (feeder) shipping services. While they are not directly associated with a direct hinterland, an indirect one does exist. The gateway ports are designed to service the needs of local, regional, and sometimes large, inland populations. They may transfer its cargo to an inland terminal to service its significant distant markets or may transfer cargo to local distribution or transload centers for further carriage.

A distribution center usually involves warehousing materials until needed while a transload center specializes in cross-docking the contents of seagoing containers into domestic trailers and the reverse, to

serve both a sorting function and the freeing up of marine containers for reuse near the port.

Some terminals may provide both gateway and transshipment services. Others are feeder terminals, where containers may arrive from either of the other two port types, but these are generally run using older equipment and the emphasis is on servicing the local population and the captive hinterland. Such feeder operations may handle a mix of containers and trailers on a single vessel, and the speed of terminal operations is not of paramount concern.

The success of container terminals is the outcome of the quality of their infrastructure and services, the operational productivity within terminal cargo handling, an efficient interface with inland transport systems, and their integration in modern supply chains.

Operating Container Terminals

The growing quantities, along with the increased size of container ships, which almost doubled within the first decade of the 21st century, imply investments in infrastructures and dredging to enable container ports to serve larger vessels. Berth and channel depth have become more important, and berth length is more crucial to servicing seagoing container flows.

They are also associated with a fundamental change in container terminal operations, as new-generation yard equipment modern cranes offer terminal berth productivity improvements. Competitive container terminal facilities provide capital-intensive cranes able to manage as many lifts per hour, or the capability to lift multiple boxes side by side at one time, as container ships do not have onboard cranes (as bulk carriers do).

Important pieces of yard equipment include rubber-tired gantries and straddle carriers to pick up or drop off containers over stacks dockside to and from nearby container stacking areas, thus being the last, or first, link in a container terminal, and container rail-mounted gantry cranes that position containers along a linear stacking yard. Technological advancement led to the introduction of automatic guided vehicles used for grounded container operations.

The latest models of the latter aim to ensure the required performance and improved reliability as well as reduced fuel and maintenance costs. An example of these are the electrically driven diesel

hybrid automatic guided vessels that are already in use, for instance at the ECT Delta terminal in Rotterdam.

As machines carry containers, and technological advancements allow for almost full terminal automatization, labor and once-powerful port labor organizations have seen their numbers, role, and influence diminish.

The productivity of the modern container terminal is highly dependent on the layout of terminals as well. Ample storage space to stack containers dock-side and berths designed to accommodate quick ship turnaround are important for effective dock-side operations between the ship, the crane, and the container storage areas. The structure and configuration of container handling operations change container terminals that tend to occupy more space for moving, storing, temporary or permanent, and providing value-added facilities for containers and the goods transported within them.

Most important is the way that the container terminal operators manage these yards. As a buffer between the container ship and the hinterland, the yard of the terminal needs to resolve operations at berth, movements within the terminal, complex stacking processes, unforeseen situations like repositioning of several containers, random pickups by customers, and delayed container ship arrivals.

Landside operations go well beyond the unloading and storing of full and empty containers, not least because container terminals serve as the only transport system that allows shipments to be used by ship, rail, and road modes of carriage. Trains and trucks operate within or near the yard, and the smooth integration of the various modes is key to terminal competitiveness. The common practice is the handling of quantities of containers through sophisticated electronically applied and monitored operations linked with supply chains.

To avoid disorganized development of container terminal facilities and allow a prompt response to changing demand, planning is as flexible as possible. This planning aims to enable anticipation of different scenarios, thereby minimizing the risk of losing markets and enhancing port profitability. It is used to resolve problems arising from both foreseen and unexpected situations, such as greater demand, new port policies, greater competition, the loss or incorporation of areas with or without equipment, and interruptions to terminal access.

Along with other factors traditionally included in the calculation of port terminal capacity, container terminal planning is commonly dynamic so as to facilitate adaptation to variations in demand and unexpected situations that, along with forecasting difficulties, mark the container market.

One of the first tasks when planning a terminal is to determine port demand and capacity. For the estimation of capacity, one needs to determine what may be expected at the port berth and the need for



Cranes at a container terminal in the port of Hamburg, Germany, in 2011. Worldwide, container terminals are handling over 50 million containers a year, and more than 100 ports handle over 1 million TEUs (20-foot equivalent units) every year.

storage capacity. In the case of an import container, capacity is calculated from the time the container is unloaded to the time it leaves the port (that is, it is equivalent to the capacity to unload a container, have it remain for some period in the yard, and eventually exit through the gate). For an export container, the steps are similar but in reverse, and for a transshipment container, capacity involves loading and unloading the container plus its stay in the terminal.

Integration in Supply Chains

Container terminals are increasingly elements in value-driven chain systems, not simply places with particular functions. With shippers transporting vast quantities of final and intermediate goods, opening the box within nearby terminal locations, or even within the terminal, is as crucial as the efficient and effective operational integration of container terminals in multimodal transport chains that allow the provision of value-added services and logistics at locations where, for example, inland depots and logistics-related service providers exist.

The terminal captures value for itself and for the chain (that is, shippers, third-party service providers), maritime companies demand further services specialization within the port area, and firms providing port or value-adding services and logistics are interested in the development of logistics pathways in which the terminal is embedded.

Container terminals are thus associated with a growing number of stakeholders. The relevant cluster involves multiple actors who are involved within the supply chain, and the operation of all of them conditions port competitiveness. This implies a change in port governance, with port authorities, that had acted as a landlords of private operated terminals only, assuming a more active role in networking these actors, in resolving collective problems like port marketing, and in promoting the interest of all those involved in the relevant container terminals cluster that operates within a given port.

All the above have led to the spatial and functional expansion of the activities of the container terminals, as well as those economic and operational activities related to it, a process described by Theo Notteboom and Jean-Paul Rodrigue as hinterland and foreland “port regionalization.” The latter associates container terminals with economic growth, yet it generates several challenges in the relations with port cities that see port terminals

seeking further expansion of their activities the more competitive they are, in turn generating a number of negative externalities such as noise pollution and usage of scarce land space.

Terminal Entry

The changes in the organization of container handling resulted in the transformation of port governance. A key move has been the progressive entry of private terminal operators, an opportunity for entry and rise of international terminal operators. This implied a fundamental shift in the concept of “port,” from one whose operations are coordinated and controlled by a public agency whose actions are shaped by local and regional interests to one that is made up of independent terminals whose activities are determined by the commercial interests of its international long-term lessors—a shift termed by Brian Slack and colleagues as “the terminalisation of seaports.”

The acquisition of a concession to provide terminal services, along with variable commitments to infrastructure building, is the dominant mode of private entry in all continents. Governments or port authorities commonly retain the initiative of planning. Procedures for awarding concession differ between regions, within countries, even within a given port.

In Europe and the United States, where port authorities transfer the rights to provide port services to the private sector, dual practices exist, as calls for tenders for a new terminal are combined with direct talks with incumbents, whereas corporatization and listing of the seaport in the stock exchange is seen as a precondition in some cases. In the booming ports in China public–private joint ventures involve public-sector operators that retain a share of at least 75 percent and foreign investors.

Different types of container terminals emerge as regards the responsible operator. Some remain public or state run, with facilities used by all commonly on a first-come, first-served basis. Others are operated by terminal operators that invest directly in operation, handling facilities, and, when applicable, the construction of the terminal. Stevedores, the companies that act as terminal operators, expand into new markets to replicate their expertise in terminal operations and to diversify their revenue geographically. The Port of Singapore Authority (PSA)

is the largest global terminal operator coming from a stevedore background.

Similarly, shipping companies, either alone or in collaboration, also operate container terminals. These terminal facilities operate on a single-user-dedicated base, where major shipping lines sign long-term contracts for exclusive terminal use, or alternatively are open to third-party shipping lines. In many cases hybrid structures are formed with separate business units or sister companies active in terminal operations. APM Terminals, a sister company of Maersk, is the largest global terminal operator from this background. Joint ventures of carriers and terminal operators also exist, whereas there are fewer partnerships among the shipping lines that have multi-user long-term contracts to share out the terminal usages.

Ports witnessed the emergence of international terminal operators operating a global portfolio of container terminals across various ports, regions, or countries. In the 1990s carriers and terminal operators doubled their involvement into terminal management. Since then, international terminal-operating companies have continued to take a bigger share of the global container handling market at the expense of both family-controlled stevedores and state-owned enterprises.

In the last decade they were joined by the various financial interests ranging from investment banks and retirement funds to sovereign wealth funds attracted to the port container terminal sector as an asset class and for revenue generation potential. The majority have an indirect management approach, acquiring an asset stake and leaving the existing operator to take care of the operations. Others manage directly the terminal assets through a parent company, an example that marks the extent of this finance being Dubai Ports World (DP World), a branch of the Dubai World sovereign wealth fund, marking the extent of that financialization trend.

Today the four major container terminal operators—Port of Singapore Authority Corporation (PSA), Hutchison Port Holdings (HPH), Dubai Port World (DP World), and APM Terminals—handle 46 percent of global container trade and the 10 major ones approximately 65 percent of world container traffic, whereas a decade ago they handled 45 percent only.

These trends changed the nature of the competition between container terminals and the ports

that host them. The competition between ports in different locations for the handling of containers, commonly termed “interport competition,” is now accompanied by intraport competition, a situation where two or more different terminal operators have jurisdiction over respective terminal areas, from berth to gate, within the same port and are vying for the same market. In bigger ports, for example Hong Kong, it takes the form of intraterminal competition with companies competing to provide the same services within the same terminal.

Responding to market development, port policies with reference to container terminals have been developed. The emphasis is on the integration of ports to multimodal transport networks. It is also on the facilitation of intraport competition that allows for operational flexibility and innovation, and limits excess rent seeking by those operators maintaining monopoly positions. With few exemptions, port authorities develop policies to promote it whenever the scale of the operation is such that it allows more than one terminal operator to be active in a specific port.

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See Also: Containerization/Container Shipping; Freight Handling; Globalization; Maritime Administration; Maritime Industry; Port Facilities; Ships; World Container Ports.

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Containerization/ Container Shipping

Containerization is a process in which freight movement by marine, rail, and truck modes and intermodal terminal operations are gradually transformed so that most manufactured cargo moves in shipping containers in a range of standard sizes that are loaded and unloaded by specialized container-handling cranes and vehicles at container terminals. The efficiency of cargo handling, intermodal transfer, and turnaround time at ports have greatly increased, contributing to a reduction in transportation costs for many types of manufactured goods.

Historical Development of Containerization

From the practical inception of for-hire trucking in the 1920s, railways began to carry straight trucks and semitrailers on flatcars between major railway terminals. Known colloquially as “piggy-back” or more formally as “trailer-on-flatcar” (TOFC) service in the United States and Canada, railway flatcars were modified with folding bridges so that vehicles could be driven from specialized loading docks over the length of the train. This cumbersome and laborious “circus-style” of train loading offset the fuel and labor cost savings of shipping individual trucks by rail over long distances. In the United States, piggy-back service faced serious obstacles from the Interstate Commerce Commission (ICC), which became responsible for interstate trucking in 1935, and the Teamsters, whose truck-driving jobs were at stake, also opposed the innovation. Thus piggy-back service did not really take off until the middle 1950s when the ICC relaxed its regulatory restrictions and railroad consortia such as Trailer Train in the United States were formed to rationalize piggy-back service on a number of competing railroads.

While there were a number of initiatives to reduce freight-handling costs and to containerize freight for different modes in different regions of the world, containerization in the United States was heavily influenced by the innovative spirit of one aggressive and innovative entrepreneur and former trucking company owner, Malcolm McLean. McLean was motivated to reduce the costs incurred in traditional break-bulk operations as freight was

transferred from trucks to coastal shipping routes on the eastern seaboard. Traditional truck trailers were not ideal for this purpose because “fishy-back” wasted the volume between truck trailers and the deck that was required for the wheels. McLean’s original goal was to design a shipping container for transshipment between trucks and World War II vintage T2 tankers that was inaugurated in 1956 in a test shipment over the coastal waters from Newark, New Jersey, to Houston, Texas. A variety of experiments with container shipping in the 1950s shared one common element: there was no consensus on whose standard container was to be used on a worldwide basis.

The negotiation of container standards pitted the American Standards Association (ASA) against the International Standards Organization (ISO), and within each of the two nongovernmental organizations there were competing enterprises that had already sunk considerable capital into containers that were incompatible.

By the early 1960s an American dimensional standard had emerged: 8 feet high, 8 feet wide, and 10, 20, 30, or 40 feet long, but 24-foot and 35-foot containers remained in service; in addition, a second series of smaller containers was also recognized, some measured in feet and others in meters. To realize their full potential, containers had to be stackable and secured with standard steel fittings welded to the corner post with fasteners so that any container could be locked to any other container. Most of the corner fittings were patented, and after a modified American Sea-Land design was finally adopted by the ISO as the world standard in 1965, it turned out that it would not withstand the stresses imposed by European freight-train couplings or high seas in a marine mode.

Perhaps the most notable feature of containerization was the inability of the United States and the rest of the world to negotiate a workable standard container size and locking mechanism. The question of container standards was in play for fully 10 years and the various container companies spent millions adapting their containers to a standard size and locking mechanism that was in flux. If a single container standard was elusive, the shipping industry was quicker to settle on a standard measure of container shipping, the TEU: a “20-foot equivalent unit” based on a container that is 8.5 feet by 8.5 feet by 20 feet in length.

Containerization Trends and Implications

International container traffic, measured in TEUs, has grown quite steadily at an average annual rate of about 5.3 percent. However, this growth has not come without a considerable structural transformation that is dominated by growing concentration of container ports, shipping firms, ships, shipbuilders, and container manufacturers.

First, container traffic has become more concentrated in a relatively small number of very large container ports. As a consequence of growing container ship size, only the largest ports are accessible to long-haul shipping. Thus there is a growing functional differentiation of container ports into three categories: hubs, pivot ports, or load centers handle the largest ships coming the greatest distances and offload containers for transshipment to smaller ports; direct ports are served by large ships but have no transshipment function; and feeder ports are served by only the closest load centers.

Second, container traffic is carried by container ships that are owned by a diminishing number of very large shipping companies. Shipping companies are consolidating by mergers; one of the most notable is the takeover of Sea-Land by Maersk, creating the largest single container shipping company in the world. The concentration of corporate power is often indirect when shipping companies undertake strategic alliances with other shipping companies or with container port operators. Strategic alliances give shipping companies greater bargaining power with port authorities, terminal management companies, and landside carriers.

Third, container ships are growing larger and more fuel efficient. The first generation of container ships in the 1960s carried up to about 1,000 TEUs. Post Panamax container ships now have a capacity in excess of 10,000 TEUs with operating costs about one-third of a Panamax vessel of about 4,500 TEUs. Indeed, a new generation of Malacca-max vessels of about 400 meters in length and carrying 18,000 TEUs will have a draft of up to 21 meters, the maximum practicable draft for eastbound ships serving Singapore and east Asian ports.

Fourth, the number of service providers to the container shipment industry is growing more concentrated. Over 80 percent of all container ships are now built by just four shipbuilders: one is Japanese and three are Korean. Virtually 100 percent of all shipping containers are now manufactured in China.

Containerization of marine, rail, and road traffic has been a significant technological change affecting transportation services around the world. It is an ongoing process of growth and structural change that has facilitated globalization and international trade but with ultimate impacts that are uncertain.

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See Also: Container Terminals; Freight Handling; Globalization; Maritime Administration; Maritime Industry; Port Facilities; Ships; World Container Ports.

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Cordon Travel

Despite the great diversity among the cities of the world, almost every metropolitan area in the modern world faces problems surrounding rush hour traffic. The exact nature of traffic-related problems may have regional variations, but all cities would like to minimize those problems. Unfortunately, most cities are not able to add new roads due to space restrictions and the significant resources required for such projects. For these reasons, administrators and researchers have investigated and, in some cases, implemented fees for traveling through high-traffic metropolitan centers, often referred to as "cordons."

While tolled cordon areas are not widespread in the United States, the concept is similar to that of toll roads. The roads passing through these areas are reserved for people who need to be someplace

particularly quickly. An additional similarity between cordon areas and toll roads is that they have both become easier to maintain due to automated tolling technologies.

Why and Where Cordon Fees Exist

Such congestion pricing is most commonly put into place in cordon areas, which are restricted areas surrounding city centers. Outside of military applications, cordon areas are typically set up for the purpose of controlling the number of vehicles entering a city center. Cordon travel is based on certain capitalist economic theoretical assumptions. The proponents of cordon travel point out that, based on the laws of supply and demand, traffic occurs because demand exceeds supply. This lack of supply (that is, road space) causes a shortage; thus, traffic jams ensue. From this theoretical standpoint, fees are set to determine an “equilibrium price.” At such a price, traffic would be acceptable in density (thus traffic jam free) and the price of travel would be low enough to be acceptable to the greatest number of commuters possible. This same set of free market-oriented economic precepts could also be applicable to other services, including trains, buses, telephones, electricity, and other public services and utilities.

There are a number of problems city administrators address that could be solved by limiting traffic to certain areas of a city. First, there is a certain cost of maintaining roads in the form of mowing green spaces, patching roadways, and other tasks that require outlay for materials costs and worker wages. Cordon fees would both lessen the wear and tear on the roads in a target area and pay for at least a portion of the upkeep. Paid cordon travel could also be utilized to limit air pollution and noise pollution; the benefits of such an improvement are obvious.

It is also argued that if traffic through cordon areas were lowered, there would be a corresponding lowering of traffic accidents. Finally, there are more abstract economic costs of traffic congestion, such as worker hours lost by being late for work. Thus, enterprises located in the cordon area may see an increase in productivity due to the fact that employees are able to arrive at work on time more reliably.

Electronic toll collection technologies could greatly expedite implementing potential cordon travel fees. These technologies have simplified the

infrastructure needed to enact cordon travel by requiring only an array of sensors and cameras as opposed to a series of toll booths, worker wages, and all of the amenities needed to allow workers to operate toll booths (bathrooms, air conditioners, break rooms, etc.). Therefore, a greater number of cities are either considering or planning to establish cordon areas.

While the most common method of establishing corridor fees is through cordon travel, there are alternate methods to achieve this goal. Freeways passing through a downtown area may be turned into toll roads; passengers may then be charged by the distance traveled through the targeted area. In this situation, the toll may be switched on or altered during peak travel times. This can be established through either toll booths or electronic tolling systems, such as EZ Pass. Preexisting high occupancy vehicle lanes (HOV) could also be used to establish a cordon travel system.

Typically, HOV lanes are designated only for vehicles with a certain number of passengers (typically two, including the driver). If administrators wanted to use HOV lanes for cordon control, they could issue special licenses to individuals who regularly travel to targeted areas that would allow them to use these lanes without following standard HOV rules. This would have the effect of directing those who regularly travel to the target area to the HOV lane.

Cordon fees were first implemented in Singapore as part of the Singapore Area Licensing Scheme in 1975. It took some time for other areas to accept such fees, in large part due to hurdles poised by preexisting infrastructure. Later implemented systems went into place in Rome (2001), London (2003), Stockholm (2006), and Milan (2008). Cordon pricing has been less politically popular in the United States, but cities currently considering such a price scheme include San Francisco, Miami, Minneapolis, Chicago, and Seattle.

It would be incorrect to believe that paid cordon travel has been implemented everywhere it has been considered. This type of pricing has been rejected either unilaterally or democratically in Hong Kong and certain areas of the United Kingdom (including Edinburgh, West Midlands, and Greater Manchester). Large-scale cordon pricing has also been rejected in New York City; however, some concessions have been made in this regard by

charging greater amounts on certain expressways and the George Washington Bridge during certain peak hours.

Concerns and Criticisms

Cordon travel fees are not without their detractors. The primary objections bring up not only the research and economic theory backing up cordon fees but also the potential negative social impact that could occur if cordon fees were put into place. Opponents to cordon travel schemes argue that cause and effect has never been properly established in the relationship between setting up cordon fees and lessening traffic.

These critics argue that traffic jams are not purely based on the number of cars on the road, and that the number of cars is but one of very many variables that contribute to traffic jams. Put very simply, traffic jams are caused by many people trying to do the same thing at the same time, and the number of cars needed to cause a traffic jam is fairly small.

Not all objections to cordon fees rely on the assumption that the theory behind such schemes is faulty. If we are to assume that cordon fees do actually keep people out of areas at peak times, it can then be easily argued that these fees are harmful to businesses within the target area, as at least a portion of potential customers would be kept away from those shops. This complaint is exacerbated by accusations of corruption. Beyond simply being inconvenient, roads are built with taxpayer money and cordon fees adversely impact those with fewer resources to pay additional costs for use of those roads.

Those critics who are not so concerned with theoretical flaws or the economics of business point out that cordon fees could have negative impacts on society. At the very least, enacting tolls to areas that were previously free to access would be very unpopular. Critics have also questioned whether the fees are actually enacted for the greater public good or whether these fees are actually put in place as an additional revenue stream for society's elites. The theory behind cordon fees assumes that

many are traveling to cordon areas when they do not have to.

This thinking may be backward if the areas in question are primarily business oriented. If so, the vast majority of travelers to the cordon zone will continue to congest the roads, and yet another fee will be imposed on working people who may not be able to afford the additional cost. Finally, critics argue that the implementation of fees "unduly" benefits those who live in cordon areas, as they do not have to pay the fees to access employment; this point is especially sharp if those who live in the cordon area are of high socioeconomic status.

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See Also: Automobile Access Programs; Benefit–Cost Analysis of Transportation; Park-and-Ride/Kiss-and-Ride Lots; Privatization of Public Transit.

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D

Demand-Responsive Transit, Evaluation Studies of

A demand-responsive transit (DRT) system is a means of transportation for the public that is known by its flexible routing and scheduling. Having the availability of this type of transportation system has been especially beneficial for that segment of society with limited access to conventional public transportation. According to the Transit Cooperative Research Program (TCRP), there are about 1,500 rural and 400 urban DRT systems in the United States.

The definition of DRT has been continuously developed throughout the years. It is generally characterized by its flexible routing and shared rides, and the Federal Transit Administration defines it as a “transit mode comprised of passenger cars, vans or small buses operating in response to calls from passengers.” DRT has been identified with other terms such as dial-a-ride, flexible transport service, and demand-responsive service. With DRT having a large range of definitions, it confirms that not all providers of DRT systems are identical. DRT serves a variety of riders and is not focused on any specific type of rider.

Fixed-route transit (FRT) and DRT systems are the two broad categories in transit systems. The

most cost-effective are the FRT systems having a large loading capacity and a predetermined schedule. In comparison with fixed-route services, the DRT still has low productivity and high per-trip costs. The flexibility of the DRT system is what makes it more appealing than FRT. The movement of individuals from inner cities to the suburbs has created less demand for the fixed-route transit options and also increased the price per rider. Therefore, in the less dense areas the DRT system can be more cost-efficient by having dispersed trip destinations.

Since the 1960s, DRT systems have been proposed, although it was not until the 1970s that the simple DRT systems were implemented in the United States. During this time, the manual dispatching system in use was expensive and excessive. Since then, there has been an incredible increase in the use of DRT systems. A large increase in 1990 was due to the Americans with Disabilities Act (ADA), which required the availability of “paratransit” services for individuals unable to use the fixed-route services. Many of the riders who currently use DRT are in rural areas with limited access to a privately owned vehicle.

Based on a Government Accountability Office survey, since 2007 the demand for ADA paratransit trips in the United States increased for some transit agencies, and costs for providing the trips remained high. The average number of annual ADA paratransit



A National Express “dot2dot” vehicle outside a terminal at London Heathrow Airport in 2008. Many such airport express vans and buses are forms of demand-responsive transit.

trips provided by a transit agency increased 7 percent from 2007 to 2010; from 172,481 trips in 2007 to 184,856 trips in 2010. Increases in demand for ADA paratransit services were driven by the 10 largest transit agencies, measured according to the population size of their service areas. Also, ADA paratransit trips are much more costly to provide than fixed-route trips. Similarly, the average cost of providing an ADA paratransit trip in 2010 was \$29.30, an estimated three and a half times more expensive than the average cost of \$8.15 to provide a fixed-route trip. The average cost of providing an ADA paratransit trip increased 10 percent from 2007 to 2010.

Flexibility and the Role of Technology

Within the DRT system, scheduling and routing is a flexible trait. Having the ability to create different schedules and routes is what makes DRT different from an FRT service. Some DRT services allow scheduling up to two weeks in advance, and some even allow same-day scheduling if room is available. Those DRT services that provide ADA paratransit are required to accept a trip on a next-day basis. Among the added benefits of the DRT system, the flexible scheduling remains essential.

Research conducted by Kai Monast indicated that by applying a “well-planned scheduling structure,” the performance of DRT can be further improved. Similar studies show that implementation of more advanced technologies could improve the DRT system. Kurt Palmer discusses in his research how the advanced technologies have improved the DRT systems’ efficiency. The benefits of these advanced technologies include the response to changed client schedules and improvements to the reliability of trip schedules.

Significance and Performance

Many perceive a DRT system working in only dense areas with a greater number of destinations. However, the TRCP Report mentions that there are a greater number of DRT systems in rural areas than there are in urban settings. The DRT system in rural areas proves useful by helping improve the mobility of many individuals who do not have access to privately owned vehicles.

DRT services in urban areas tend to experience high demand with simultaneously high costs. For example, the urban region of King County, Washington, proved to have low ridership and high operating cost. The DRT performance within urban areas is not as efficient compared to suburban and rural areas because of the traffic congestion and complicated street networks. There also tends to be greater competition in urban areas with multiple services, including buses and taxis. Because there is such a high demand for DRT systems in dense urban areas, studies have been done to improve their efficiency. In Europe, Jenny Mageean argued that by implementing telematics-based DRT, limitations in urban areas could be addressed.

The DRT systems have created better options for rural areas, since most lack any form of public transportation. With greater flexibility, the DRT gives rural populations greater access to medical facilities, which are usually located around urban centers, as access to medical facilities becomes less difficult when the distance is served by the DRT system. Thus, mobility between rural and urban areas is served incredibly well by the DRT system. These rural areas now have a greater amount of accessibility and are able to do so in a shorter time period. With the greater availability of rural to urban transport, communities are provided better accessibility

not only to medical facilities but also to other critical services.

Performance is an important factor to evaluate in DRT to understand what does work and fix what could work better. The performance of DRT systems has been widely researched for the last decade. When it comes to the performance of the DRT systems in the world, many studies have shown that they desperately need improvement. Monast and Joshua Worthy researched the rural DRT system, concluding that it is inefficient to deliver, time-consuming to schedule, and requires a large vehicle fleet. Although there are positive and negative aspects to rural DRT service, helping these communities have greater mobility to “activity sites” outweighs the hardships within the service.

Each study looks at different variables when assessing the performance of the DRT systems. Luca Quadrifoglio's performance measures include total trip miles, deadhead miles, and fleet size, while Palmer includes passenger miles and trips per vehicle as well as operating expense per passenger trip and mile in his performance measurement. Although both look at different variables and find separate results, they both established that there still needs to be further research done to assess the performance of the DRT system. The TRCP report indicates that, because of the growing demand for service, many DRT systems are under pressure to improve their performance. This TRCP report used similar performance measures as did Palmer.

Another factor studied in regard to performance are traffic conditions in urban areas compared to rural areas. In urban areas, there tends to be a great deal of congestion, which impacts the DRT systems' overall performance. Urban and rural areas should have different variables reviewed when assessing performance because they have different factors influencing them. In rural DRT, according to the TCRP, the performance variables should also include deadhead time and miles, which were also included in Quadrifoglio's study on DRT performance. By researching the factors influencing DRT performance, both urban and rural areas can improve their systems.

Environmental Benefits of DRT

The environmental impacts of different road public transport were documented by different researchers, providing a framework for the assessment of

transit's environmental impacts. With the use of DRT systems, the use of POVs will somewhat decrease, and vehicle emissions will be decreased simultaneously as well. Studies indicate that creating better transit scheduling in both FRT and DRT systems will result in fewer environmental impacts. Many of the DRT services, apart from the social and mobility objectives, have environmental motivations. They are meant to reduce the use of POVs and to encourage a modal shift away from the car. In doing so, many agree that DRT is one of the many ways of bringing about a sustainable transportation system.

Demand-Adaptive System

The newer transit system known as the demand-adaptive system (DAS) displays features of both fixed-line bus service and DRT. The DAS bus line has mandatory stops in its schedule, which follows the fixed-line bus service pattern. On the other hand, it also follows the DRT service by giving individuals the option to issue requests for minor detour stops. This DAS service creates strategic plans in the scheduling phase, compared to DRT service in which schedules are created a short period before issuing service. Although DAS provides some flexibility in its service, the DRT still offers the maximum flexibility for users.

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See Also: Elderly and Disabled Travelers; Transit Demographics; Transit Systems.

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Department of Transportation Act of 1966

President Lyndon B. Johnson signed the Department of Transportation Act (H.R. 15963) into law (P.L. 89-670) on October 15, 1966. It was an idea that had taken almost 100 years to turn into reality. Similar attempts to create the department had failed at least 17 times before. The law became effective on March 30, 1967. Upon signing the bill, Johnson noted that by 1966 the transportation sector had become the largest of all American industries, employing millions of people. Creating the Department of Transportation (USDOT) was intended to allow the president to consolidate 35 transportation-related programs that had previously been divided among seven departments and

agencies. Altogether, Johnson predicted that the new Department of Transportation would bring 100,000 employees under the USDOT umbrella and that it would operate with an annual budget of some \$6 billion.

The Department of Transportation Act of 1966 defined the functions of USDOT as modernizing and unifying national transportation policy, promoting safe travel, ensuring that the most up-to-date technology was employed throughout the transportation sector, strengthening partnerships with other levels of government and with the private sector, and improving global transportation links. The Department of Transportation was the 12th cabinet-level department. Alan Boyd, a former chief of the Civil Aeronautics Board (CAB) and the chair of Johnson's USDOT task force, became the first secretary of transportation. The USDOT held the Pageant of Transportation on April 1, 1967, to celebrate its official opening. For the first time in U.S. history, federal oversight of highways, railways, aviation, and maritime operations was consolidated within a single department.

Background

Between 1950 and 1967, responsibility for representing the interests of the transportation sector had resided partly with the Office of the Undersecretary of Transportation, which operated under the Department of Commerce. Oversight of other aspects of the transportation sector was divided among the Department of Treasury, the Department of the Interior, the Interstate Commerce Commission, the Civil Aeronautics Board, the Federal Aviation Agency, and the Saint Lawrence Seaway Development Corporation. When considering all federal transportation responsibilities, highway transportation functions were dispersed among 12 agencies that had been created between 1893 and 1966. Eighteen departments oversaw rail transport functions during that same period. Between 1843 and 1967, 25 agencies held federal responsibility for maritime operations. Aviation functions had been directed by 18 federal agencies between 1926 and 1967.

In addition to these transportation functions, federal responsibility for urban mass transit was divided between the Office of Transportation, Housing and Home Finance Agency and HUD's Urban Transportation Administration. Transportation safety research functions were assigned to

the National Aeronautics and Space Administration (NASA) under the Electronic Research Center (1965–66) and the Electronic Research Center, Office of Advanced Research and Technology (1966–70).

There were many reasons the Department of Transportation was created in 1966 after so many previous attempts to establish a voice for the transportation sector had failed. One was the legislative expertise of Lyndon Johnson, which had been honed by 10 years spent representing Texas' 10th Congressional District in the House of Representatives (1937–47) and 13 years in the U.S. Senate (1948–61). In his 1966 State of the Union address, Johnson had pledged his support for the creation of a national department of transportation.

A second reason that DOT was finally created in 1966 was the conviction of Najeeb E. Halaby (1915–2003) that the time was ripe. Halaby was the Dallas-born son of a Lebanese-Syrian father and an American mother. He had fallen in love with flying as a young man after witnessing a Charles Lindbergh flight. After enlisting in World War II, Halaby helped set up a test-pilot school for the Navy and had flown the world's first combat jet. In 1961, President John F. Kennedy chose Halaby to head the Federal Aviation Administration. In that position, Halaby became frustrated over the fact that transportation was given no voice in the president's cabinet. He was also convinced that the Department of Defense had intentionally shut the Federal Aviation Agency out of policy discussions on supersonic transport. Others who believed that the time had finally come to establish a national department of transportation included Budget Director Charles Schultz, Presidential Assistant Joseph A. Califano, Jr., and Alan S. Boyd, who became the first secretary of transportation.

Other reasons that the time was ripe for passage of the Department of Transportation Act of 1966 involved the growth of the transportation sector in conjunction with concerns over issues caused by that growth. Those issues involved areas such as traffic congestion, crowded air lanes, accidents and safety abuses, outmoded equipment, and inefficient service. By 1965, the American highway system had grown to more than 3 million miles of paved highways and streets, and more than 90 million vehicles traveled those roads. Within the aviation industry, 100,000 airplanes traversed more than a billion

miles. The transporting of freight involved moving 1.5 trillion ton miles of cargo along railroads, highways, and waterways.

Lyndon Johnson had asked Alan S. Boyd (1922–) to chair a task force that was charged with laying the groundwork for writing the law that would create the national department of transportation. Boyd, a lawyer who had served with the Army Troop Transport Command during World War II, had been appointed to the Civil Aeronautics Board by President Dwight Eisenhower in 1959 and had become chief of the CAB under President John Kennedy. In 1966, Boyd was serving as Undersecretary of Commerce for Transportation within the Department of Commerce. The report of the Boyd Task Force was released on October 22, 1965. It called for the creation of the U.S. Department of Transportation and recommended that the Federal Aviation Agency, the Bureau of Public Roads, the Coast Guard, the Saint Lawrence Seaway Development Group, the Great Lakes Pilotage Administration, the Car Service Division of the Interstate Commerce Commission, the subsidy function of the Civil Aeronautics Board, and the Panama Canal be placed under its jurisdiction.

From Law to Reality

By March 6, 1966, the Johnson administration had a bill ready to submit to Congress. However, once Congress began working on the bill, it was significantly weakened from the bill submitted by the president. Nevertheless, some 95,000 employees were ultimately moved into the new Department of Transportation. Most of them worked for the Federal Aeronautics Agency, the Coast Guard, or the Bureau of Public Roads.

The overriding goals of the newly created Department of Transportation were related to safety, consumer protection, planning and research, and coordinating and assisting state and local governments in meeting transportation needs. Section 2 of the Department of Transportation Act of 1966 identified the specific purposes of the new department as coordinating and administering all national transportation programs; facilitating the development and improvement of the U.S. transportation sector; coordinating transportation activities carried out by governments, carriers, and labor; promoting technological advances within the transportation sector; providing leadership for the entire

transportation sector; and advising the president and Congress on transportation needs through policy and program recommendations.

When setting up the Department of Transportation, Alan Boyd immediately began addressing vehicular safety issues. By January 1967, USDOT had issued 21 new motor vehicle safety standards. Two months later, the National Highway Safety Advisory Committee was established to provide advice, make policy recommendations, review transportation policies and programs, and issue reports. Members of the committee included the secretary of transportation or a designated USDOT representative, the Federal Highway Administrator, the National Highway Traffic Safety Administrator, and 35 members appointed by the president. Participation by federal employees was limited to no more than four members. All other members were to be representatives of state and local governments, transportation experts, or transportation-sector owners and officials.

Boyd continued to serve as secretary of transportation until 1969 when Republicans took over the Oval Office following the election of Richard Nixon. During his time in office, Boyd concentrated on issues involving airport modernization, air traffic control, driver education standards, and the reduction of alcohol-related accidents. He also worked with Lady Bird Johnson, the First Lady, on her highway beautification program. Because the needs for federal involvement in mass transit had become so urgent, the Department of Transportation Act of 1966 also included a provision for addressing mass transportation issues. Dissatisfied with the congressional effort, in 1968 Johnson transferred responsibility for overseeing mass transit from the Department of Housing and Urban Development (HUD) to the Department of Transportation. Despite his accomplishments as transportation secretary, Boyd was faulted for failing to revitalize passenger rail service.

In 1970, President Nixon transferred the Electronic Research Center from NASA to USDOT. In 1981, just as Johnson had urged Congress to do in 1966, the Maritime Administration was transferred from the Department of Commerce to USDOT.

It had generally been agreed upon that one of the major functions of the new Department of Transportation should be to oversee the safety of motorists on U.S. roads. According to the National

Highway Traffic Safety Administration, 50,894 people were killed in vehicular accidents in 1966. If nothing were done, the then current rate of 5.5 deaths per 100 million miles of travel was predicted to rise dramatically. In response to these concerns, in 1966 Congress also enacted the Highway Safety Act, which created the National Highway Traffic Safety Administration (NHTSA) as an agency within the Department of Transportation. Assisted by federal funds, state governments were required to work with the NHTSA and USDOT in creating their own highway safety programs.

By 1983, the Department of Transportation Act had been amended four times, but most amendments dealt with language conformity. A 1983 amendment, however, was chiefly concerned with environmental protection. That amendment instructed the secretary of transportation to work with the secretary of the interior, the secretary of HUD, and state and local communities to preserve the environment and historic sites and to protect the natural habitats of wildlife and waterfowl.

The major reorganization of the executive branch that followed the terrorist attacks of September 11, 2001, transferred the Coast Guard and USDOT Operating Administrations (renamed Transportation Security Administration) to the newly created Department of Homeland Security.

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See Also: Bureau of Public Roads; Federal Highway Administration; Maritime Administration; National Highway Traffic Safety Administration; U.S. Department of Transportation.

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Deregulation

Deregulation was a politicoeconomic movement that began in the late 1960s in a drive to undo the regulatory controls on transporting of goods and people. The regulations had been imposed by popular demand to protect the public from rapacious shipping companies since the 1870s. Deregulation decommissioned the regulatory work of a century in order to eliminate its harmful effects. Regulation of shipping tariffs and other features of the transportation industry began in the United States in the 1870s in an effort to prevent overcharging from the public's point of view. The railroads were conducting business in an unregulated market economy, providing services to millions of customers. However, their pricing practices and other customer concerns were often viewed with hostility. In many cases they were charging high freight rates because only one railroad was available for shipping crops or livestock.

Customer complaints were often ignored in an era of ever-expanding trackage hauling ever-growing lots of goods. Politicians responded to the complaints of voters and interests dissatisfied with railroad services by creating the Interstate Commerce Commission (ICC) in 1887. The ICC was supposed to regulate railroad freight rates by fixing

price ceilings in order to prevent the railroads from reaping what would be deemed excessive profits. However, the ICC had little in the way of enforcement power. It was also weakened in its regulatory powers by adverse Supreme Court decisions.

During the administration of President Theodore Roosevelt the Hepburn Act (1906; 34 Stat. 584) was adopted. This act began the expansion of the ICC's authority from regulating railroads to regulating all common carriers except airplanes. The regulatory controls were widened and extended in the period between 1920 and 1940 to other passenger common carriers and to the growing aviation industry. The Motor Carrier Act of 1935 (P.L. 74-255, 49 Stat. 543) was an amendment to the Interstate Commerce Act. It instituted federal regulation of interstate bus lines and airlines as a form of public utility monopoly.

The regulatory power of the ICC was based upon the expressly delegated power of Congress to regulate interstate commerce under Article I, section 8 of the U.S. Constitution. The ICC's regulation of motor carriers was modeled after its regulatory powers over railroads. The legal effect was that the ICC had major economic control of the motor carrier business because its control chose the companies that could be motor carriers, the kinds of services they could offer, and the rates they could charge.

Like the Motor Carrier Act of 1935 the Civil Aeronautics Act of 1938 (CAA; PL 75-706, 52 Stat. 973) was based upon Congress's power to regulate interstate commerce under Article I, section 8 of the Constitution. The CAA created the Civil Aeronautics Authority in order to centralize safety regulations but did so in a way that balanced commercial interests. Key provisions of the act were linked to the authority of the U.S. Post Office to carry the mail. Contracts to carry the mail with airlines were federal issues.

1950s

By the early 1950s the ICC was regulating almost anything considered transportation in the United States. It regulated not only railroad, bus lines, and airlines but also bridges, internal waterways shipping, intercoastal shipping, ferries, and pipelines. However, most of the freshwater barge and boat traffic as well as the truck traffic had been exempted by a variety of laws.

The Transportation Act of 1958 gave the ICC jurisdiction over passenger train service in order to coordinate the ICC's decisions with state commissions that regulated passenger trains. However, the decisions of the ICC under its authority were widely criticized as not rational from a business perspective. Also irritating to many in the public was the very slow pace at which the ICC approved mergers. The repeated failures of the ICC to act in a timely manner ended in serious financial harm and loss of service to the public as some railways failed. But this was of not apparent concern to the ICC. Its overregulation reached the point where it required railroads that were losing money to continue to operate, which deprived them of property without proper due process of law.

1960s and Beyond

In 1962 President John F. Kennedy called upon Congress to address the problem of transportation regulation. In 1966 President Lyndon B. Johnson was able to sign legislation establishing the Department of Transportation. By the late 1960s calls for deregulation of transportation were gaining strength. In the 1970s and 1980s Congress began to pass deregulation laws. The Airline Deregulation Act of 1978 (P.L. 95-504, 92 Stat. 1705) sought to remove the government from control over commercial aviation. The regulatory powers of the Civil Aeronautics Board were phased out so that market forces could affect the airline industry and the prices paid by passengers for tickets. The main regulatory power remaining was that of control of safety standards.

Railroad deregulation began when Congress passed the Railroad Revitalization and Regulatory Reform Act of 1976 (P. L. 94-210, 90 Stat. 31) also known as the "4R Act." Full deregulation came with the passage of the Staggers Rail Act in 1980 (P. L. 96-448, 94 Stat. 1895). The Staggers Act moved to end the regulatory structure that the ICC had built since its inception in 1887. Its provisions included removal of certain regulations so that carriers no longer needed ICC approval to enter into contracts with shippers to set prices and services. The new economic realities were that the railroads were no longer the giants of transportation. The development of the Interstate Highway System had moved millions of people off passenger trains and into automobiles that cruised at speeds as good as those of trains at lower costs. In addition, transfer trucks

were hauling millions of tons of freight that had previously been carried by the trains.

The Motor Carrier Act of 1980 (P. L. No. 96-296, 94 Stat. 793) deregulated the trucking industry. Many new trucking firms were then able to enter the hauling business and to compete. In 1996 President Bill Clinton signed the Interstate Commerce Commission Termination Act P.L. 104-88, 109 Stat. 803). The final act of the commission before its death at the age of 108 was for its chairman to transfer its remaining functions to the new agency, the Surface Transportation Board.

Observers have noted that many of the rules and regulations of the ICC have remained in effect, for example, its loss-claim procedures. In addition, its orders, rules, permits, and much more are still law. The reason for deregulating the transportation industry was to allow for greater competition. It was believed that more competition would stimulate more productivity, efficiency, and lower prices. For airlines, the value of the companies went down drastically as many in the competitive struggle went bankrupt. The costs that drove them down were often related to fluctuations in fuel prices due to political forces beyond their control and to labor costs that had developed when the industry was regulated.

Deregulation has been beneficial to many consumers and to some firms seeking to enter the transportation business. However, for many companies the results have been economically unfavorable.

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See Also: Airline Deregulation Act of 1978; Department of Transportation Act of 1966; Interstate Commerce Commission; Interstate Highway System; Motor Carrier Act of 1980; Surface Transportation Board.

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Derived Demand

Derived demand is the demand for an intermediate good (or service) that results from the demand for or provision of another good (or service)—such as the demand for vehicles, gasoline, and parking spaces that occurs in order for people to enjoy time with friends, get food shopping done, sell their products in town, or supply their labor to employers. W. J. Baumol and A. S. Blinder provide the example of demand for fertilizer as derived from the underlying demand for corn, the final product. An increase in the demand for corn drives up corn prices, which drive up the marginal revenue product (MRP) of—and therefore demand for—fertilizer.

Transportation is largely a derived demand because its pursuit stems from a desire to engage in other activities. Generally, travel loses its value without the activities at the trip's origin and destination. Often modeled as a “dis-” utility or cost of engaging in the activity of interest, travel costs rise with travel time and trip expenses. Travel time has great value, and travel time savings typically constitute the greatest share of benefits that emerge from transportation system improvements. What differentiates transportation from other intermediate goods with derived demand is that it is not a stand-alone final product or service. “Unused” transportation

movements (for example, underutilized highway capacity at a specific time and place or unsold seats on a flight) cannot be stored for use at a later time.

J.-P. Rodrigue et al. defined two types of transport-based derived demand. Direct derived transport demand directly results from activities. For example, in the case of employees commuting to work, the demand for transportation between residences and workplaces is a direct result of supply (households) and demand (employers) for labor. In freight movements, travel is a derived demand resulting from a supply chain moving other intermediate and final goods, such as raw materials, parts, and finished products. Indirect derived transport demand results from other transportation demands (which presumably are derived themselves from nontransport activities). For example, demand for roadside assistance (of a tow truck or emergency vehicle) results from the travel demand of the vehicle requiring assistance. In freight movement, warehousing demand can be considered an indirect derived demand, since it only exists as a result of differences between commodities available where they are produced and where they are consumed.

Interestingly, some relatively recent studies have challenged the conventional idea of travel as a derived demand. P. L. Mokhtarian and I. Solomon provide conceptual and empirical evidence to



While transporting workers in Santa Clara County, California, the Altamont Commuter Express passes through this portion of the Don Edwards San Francisco Bay National Wildlife Refuge. A survey of nearly 2,000 San Francisco Bay Area residents found that a certain amount of commuting time was actually valued by many respondents, which contradicts some assumptions about derived demand. The average ideal commute time for respondents was 16 minutes; only 3 percent preferred a commute of 0-to-2 minutes.

highlight examples of undirected travel—like “joy rides,” recreational boating, biking for exercise, and running races. These are activities where travel/movement is the desired product, without any meaningful origin or destination. The researchers also propose that human desire for variety and curiosity may lead travelers to seek destinations (and routes) that are not necessarily the closest (shortest) in distance or least expensive to access. They argue that travel should not always be viewed as a disutility, due to some travelers’ penchant for travel itself and the various valuable activities that can be conducted during travel, including enjoyment of music or news while driving, reading while riding on transit, and the health benefits of biking and walking. In a survey of almost 2,000 San Francisco Bay Area residents, Mokhtarian and Salomon found evidence of affinity for extra travel (such as for long-distance as compared to short-distance travel, for entertainment-related travel over less discretionary/more mandatory travel, and for travel by plane over car travel). The average reported ideal commute time was 16 minutes, with only 3 percent of respondents desiring a 0 to 2 minute commute, indicating that some non-negligible commute time or at least some distance from work is of value to many.

In the freight regime, Rodrigue noted how operational scale rewards large distribution systems, centered on hub nodes that become more important than the origins and destinations themselves, as freight volumes increase. The derived demand for freight transportation becomes less related to the locations of product supply and demand as supply chain systems grow larger and more complex, challenging traditional notions of derived demand as transportation costs become embedded in supply chain costs. Finally, as transportation costs and inventory levels have fallen, thanks to just-in-time manufacture and delivery, travel delays cause significant disruptions to inventory maintenance, rendering travel time reliability at least as important as freight travel time itself.

A similar story can be told for personal travel, where value of reliability (VOR) is typically measured as the standard deviation in travel times on a set route at a given time of day. Using data for travel on the variably tolled SR-91 in Southern California, D. Brownstone and K. A. Small estimated travelers’ VOR to be \$12 to \$32 per hour of standard deviation in arrival time, or roughly 95 percent to 145

percent of the corresponding value of travel time (VOTT) on those links.

Conclusion

In summary, travel has traditionally been considered a derived demand, a by-product of other (typically economic) activities occurring at trip origins and destinations. Travel itself has been viewed as a disutility and cost, only demanded due to the desire for other goods and services. However, many contrary examples exist, in both the passenger and freight sectors. For example, leisure travel—where either the travel itself or concurrent activities performed while traveling provide value to the traveler—is not so clearly a derived demand. On the freight side, as distribution systems grow larger and more complex, travel costs becomes endogenous to the design of the supply chain system, with intermediate nodes (“hubs”) playing a more significant role in determining movements than product origins and destinations.

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See Also: Transportation, Economics of; Travel Choice; Travel Demand.

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Destination Choice Models

A destination choice model is an econometric model that can be used to understand and predict the choice of trip destination, or in other words, the choice of activity location at the destination end of a trip. They can be used alone or as part of a regional travel demand model system. For instance, the trip distribution model in a four-step Urban Transportation Modeling System (UTMS) could be represented by a destination choice model when the analysis is undertaken at the disaggregate level. (A UTMS could operate at the aggregate level of trips between zones or at the disaggregate level of trips made by individual travelers.) Destination choice models can also be used to predict the locations of activity stops in an activity-based transportation model and are referred to as location choice models in this context. The analysis of short-term mobility behavior, in the form of daily activity and travel patterns, is thus the primary purpose of destination choice models.

The choice of destination is typically a specific building (for example, work or restaurant location) or a set of buildings (for example, a shopping complex or area). However, for transportation planning purposes, destination choice models usually operate with zonal choice alternatives, which are spatial clusters of elemental alternatives. The study area is divided into zones, for instance, transportation analysis zones (TAZs) or census divisions (tracts, blockgroups, blocks), which are described by attributes such as area, population, accessibility, land use composition, distance from the individual's home or work locations.

The zonal approach is preferred because (1) the use of elemental destination alternatives would impose a much larger computational burden, (2) data is rarely if ever available at the elemental level, and (3) for transportation planning, the desired objective is the prediction of trip interchanges between zonal pairs. While zonal destination choice models are the norm, improved computational capacity in recent times has meant that analysts can define smaller zones. Accordingly, the most spatially detailed models today operate on parcels. (A "parcel" is a land area that is managed as a single, relatively large unit, defined either to consist of a single land use or based on ownership;

parcels could often, though not always, correspond to elemental destination choice alternatives.)

Model Structure and Calibration

Destination choice models are usually designed as random utility maximization (RUM)-based discrete choice models, where individual i is assumed to gain a stochastic utility U_{ij} from zone j as shown in the equation below:

$$U_{ij} = V_{ij} + \epsilon_{ij}$$

where V_{ij} is the deterministic component of the utility and ϵ_{ij} is a random (stochastic) error term. The deterministic component of the utility is hypothesized to be a function of observable attributes X_i , Y_j , and Z_j , for example:

$$V_{ij} = f(X_i, Y_j, Z_j, \theta)$$

where X_i is the vector of individual socioeconomic attributes (such as age, gender, employment status, income, possession of drivers license), Y_j is the vector of attributes of the zonal alternatives that are indicative of size (such as area, population, number of employees by occupation type), Z_j is the vector of nonsize attributes of the zones (such as accessibility, distance from the individual's work or home location), and θ is the vector of parameters to be calibrated (estimated). Different assumptions on the distribution of the stochastic error term lead to different model structures and corresponding formulations for the probability that individual i chooses destination j . The simplest of these is the multinomial logit model of destination choice.

The parameters of the destination choice model are usually calibrated using data gathered from travel diaries (for example, the National Household Travel Survey in the United States) or activity diaries (for example, the Mobidrive data in Germany) that can be used to link an individual's revealed choice of destination with observable attributes of the individual and the destination alternatives available to him/her. Since the number of zones in a region can be quite large, sometimes in the thousands, a common practice in model calibration is to draw a subset of alternatives from the universal choice set for each trip in the travel diary data set.

Discrete choice models are typically calibrated using maximum likelihood estimation techniques,

and can be estimated using standard software such as Biogeme, Alogit, and NLogit or by developing specialized code in software such as R, Matlab, Gauss, and Ox.

The Accessibility Measure

Accessibility measures are used to characterize the land use and transportation system configuration of a study area and form an important element in destination choice models. Accessibility measures commonly have two key components: the impedance factor, arising from the need to travel a non-trivial distance to the destination and exerting a damping influence on the attractiveness of the destination, and the destination factor, which is related to the characteristics of the destination and the level of opportunities available at the destination to address the needs of the individual (number and quality of shops, for example). Characteristics of the individual also affect the degree of accessibility enjoyed.

Application for Planning and Policy

Destination choice models are estimated usually for one of two purposes. One is to predict the demand for transport services arising from individuals' choice of location (or destination) for activity participation within long-term planning contexts. Therefore they form one of the steps in a UTMS or activity-based model, where they are usually implemented using simulation methods. For this purpose, it is necessary to ensure that the explanatory variables included in the destination choice model can be easily projected for future planning horizons. Moreover, the role of the destination choice model in such long-term planning contexts is to spatially peg the predicted travel demand, and therefore accuracy of prediction is a key factor in the development of these models.

The other use of destination choice models is to understand the drivers of location choice so as to influence policy in the short to medium term. For instance, will congestion pricing lead to a change in spatial travel patterns and, if so, how and to what extent? What role does travel time and cost play in the choice of location for activity participation? Clearly, this will vary depending on purpose, with work location remaining fairly inflexible in the short term and shopping location potentially being very dynamic and flexible.

Simultaneity in Decision Making

The primary decisions that individuals make to participate in activities separated over space are the location of activity participation, the choice of the mode of travel, the time of day of travel, solo versus joint travel, route choice, and the choice of trip chaining. The order in which these decisions are made is unknown to the observer/analyst and there has been no conclusive proof that any particular sequence of decisions is more likely than the other. It is important to keep this in mind while developing a destination choice model, since one or more of these decisions may be correlated with the choice of activity location.

Modifiable Area Unit Problem

The modifiable area unit problem (MAUP) refers to the statistical biases that arise due to the definition of zones, which are only aggregations of the real elemental alternatives. These biases arise from (1) a scale effect (that is, the extent of aggregation; for example, parcels versus census districts), and (2) a zone effect (that is, the shape of the zone; for example, 1 mile square versus circle of radius 1 mile). Because of MAUP the same basic data can yield different results when different zonal configurations are used. While there are no solutions to this problem, it is good practice to try different zonal configurations to test the robustness of model results.

Spatial Correlation and Heterogeneity Effects

Destination choice models, being essentially spatial models, suffer from the inherent complexities of spatial econometrics. A few of these issues are briefly discussed below.

The unit of choice for activity location decisions is not well defined. Take for instance, a shopping trip. An individual could choose to visit a specific store, a shopping mall, or a shopping district.

Activity location decisions usually involve a very large set of possible alternatives regardless of the spatial definition of the alternative. Even if the unit of choice is a zonal aggregate of shopping opportunities, the potential choice set would include all the zones in the planning region, which is still a large number (typically in the hundreds).

Due to the continuum of space, the various destination choice alternatives are likely to share common attractiveness factors (spatial correlation). For instance, we would expect zones that are nearer

each other to be more substitutable than zones that are far apart.

In addition to spatial correlation, spatial competition or agglomeration effects are also likely to play a role. Some alternatives benefit from being close to other similar alternatives (agglomeration effect) as in a shopping district, while some alternatives benefit from being away from other similar alternatives (competition effect) by capturing the market in their immediate neighborhood.

The development of an operational destination choice model usually involves some level of spatial aggregation of decision makers (individuals or households into neighborhoods or zones) and elemental units of attraction (stores or parks into zones), which ignores potential heterogeneity within the zone.

Complex model structures are needed to capture these various effects and to reduce the potential bias arising from ignoring them.

Unobserved Factors of Heterogeneity

The extent of heterogeneity in destination choice depends on the level of flexibility in the activity participation, with generally high levels of heterogeneity observed in the case of nonwork travel. The heterogeneity in choice behavior could be interpersonal or intrapersonal, and it could be due to observed or unobserved factors (from the analyst's viewpoint).

Interpersonal heterogeneity in destination choice could be a result of observed factors such as income or unobserved factors such as habit persistence. Two individuals identical in every respect may still choose different locations if one of them exhibits habit persistence or loyalty.

Intrapersonal heterogeneity in destination choice could also be a result of observed or unobserved factors. Observed factors such as the time of day may constrain an individual to choose a closer shopping location on a weekday, whereas the individual might prefer a different, more distant shopping location in the absence of time constraints on the weekend. Unobserved factors such as variety-seeking or boredom may also result in the individual selecting different shopping locations on consecutive choice occasions.

There are many such possible sources of unobserved heterogeneity, and it is important to identify and include all these within the conceptual framework for destination choice models. Omitted

sources of heterogeneity in choice models usually result in underspecified models, and in such situations a good conceptualization can help correctly interpret such models.

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See Also: Activity-Based Models; Mode Choice Models; Route Assignment Models; Trip Distribution Models; Trip Generation Rates and Models; Urban Transportation Modeling System.

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Dial-a-Ride

Demand-responsive transit (DRT) is also called demand-responsive transport, demand-responsive service, flexible transport services, or paratransit, but is most commonly known as Dial-a-Ride. In many localities Dial-a-Ride is called DART for Dial-a-Ride Transit. Whatever name is used it refers to an advanced public transport system that is user oriented. DRT is a flexible routing and scheduling system for small or medium vehicles that are engaged in sharing rides between pick-up and drop-off locations. The pick-ups and drop-offs are made to satisfy passenger needs.

DRT systems are operations with vehicles that respond to calls from passengers or their agents. A call must be placed to the DRT transit system operator. The transit operator then dispatches a vehicle to pick up the passenger in order to transport him/her to the desired destination. The system is characterized by having vehicles that do not operate over fixed routes. Nor do DRT system vehicles operate



A Dial-a-Ride van between runs in the city of York in the United Kingdom in April 2012. While private companies run some commercial services, such as airport and casino shuttles, most Dial-a-Ride routes are community not-for-profit enterprises.

on fixed time schedules, although there may be temporary situations in which a vehicle follows a schedule. Typically, the vehicle carries several passengers who are going to different locations from different pickup points. Their journey may be interrupted if new calls come in that require the driver to deviate from the planned route in order to accommodate the latest passengers to call for service.

DRT systems have been instituted in many rural areas in order to provide transport services. DRT systems are also used in areas where regular bus service is not profitable because of low demand. Funding for DRT systems may come from a local transit authority as a subsidized socially necessary transportation system. In cases where DRT is subsidized, operators may be chosen by auction or by submitting sealed bids for the right to be the transport provider. Regardless of the selection mechanism used, the transport operator is given a monopoly for DRT services it provides.

A DRT system gives people access to transportation that gets them to places and events in the community. It provides a means for people to get to appointments, activities, and social events. Trips to health care providers, places of employment, shopping centers, senior centers, education centers, or recreational places are available in a timely manner. The system is designed for people whose access to transportation or whose physical mobility is limited due to health problems. Such physical challenges

may make it difficult for people to use a regular fixed-route bus service even if it is available. What a DRT system offers is a special transportation service that is much better suited to those with a disability, providing, for example wheelchair-equipped vehicles.

Many DRT systems are funded by the local transit authority. Some are self-funded. Most are a community service that is a not-for-profit enterprise. Other DRT systems are funded by private companies for commercial reasons, such as providing customers a ride to their businesses. This may be similar to casinos providing gamblers with a ride to and from home. Some bus companies have set up DRT programs that service airports. In some cases the DRT program may compete with private for-hire shuttle bus companies.

Bus companies typically operate on fixed routes that provide transportation at approximately the same time for specified locations. Drivers must maintain the route and may not deviate from it without the likelihood of significant consequences. If special circumstance such as a matter of safety warrant the driver may deviate from the route, but in general it is not permissible for the driver leave the vehicle's assigned route.

Types

If a system is modified it can be a "deviated" fixed-route service system. In such a case the transportation service moves along a fixed route at generally fixed times. However, if the transit system is a deviated fixed-route system then the bus driver, transporter or transit provider may deviate from the assigned route in order to pick up or drop off passengers who ask for the deviation.

In contrast, a DRT system has entirely flexible routes and schedules. Shuttle bus services move between fixed locations at fixed times; DRT systems do not have fixed departure and arrival points. Other forms of DRT include paratransit services. This is a service not available to the general public. It is for qualified users who are generally people with disabilities, the infirm, or the elderly.

Share taxicab is a DRT service that is prebooked. It allows users to share taxis services when opportunities allow for such collaboration. However, a DRT taxicab share system means multiple people may be going to different locations. This may mean that a rider may be the last to be dropped off even if this creates an inconvenience.

Operations and Benefits

DRT systems operate in a defined zone rather than a defined route. The journeys begin and end inside the zone. A fixed bus route is normally unalterable. A DRT journey may be fully freeform. Some DRT systems have a skeleton route with a probable schedule. However, the journey and the schedule will vary as needed. In order to be picked up, a rider makes a call to make an appointment for pickup at some location at a time that will likely be approximate rather than fixed.

Some DRT systems may have defined termini. These will be at the two locations that can be used as a route. Locations may be an airport, a transportation exchange point, or some other location.

In order to ride on a DRT system, passengers must call a central dispatcher and request a booking for a ride. The dispatcher will inform the potential rider of the options available for pick up and the closest destination point. To connect riders and vehicles, DRT systems are using fleet telematics technology. Telematics use integrated telecommunications and informatics to track and control vehicles on the move. Global positioning systems are also integrated into computers along with automotive navigation systems. When used in road vehicles, the systems become vehicle telematics. Using fleet telematics, DRT systems can schedule and dispatch vehicles very quickly. Operators can learn their new passenger pickup points and also be assigned the shortest or quickest route to take to the newly booked passenger.

Vehicles used in many DRT systems are small minibuses due to the low ridership. However, they can also be used to provide door-to-door services for those needing paratransit. In addition, minivans can easily travel down most residential streets. In some DRT systems a passenger may be picked up or delivered by a taxicab hired by the DRT because it is cheaper or because the pickup or destination is not easily reached by the normal DRT vehicle.

Studies of the impact of DRT systems have found that their services can reduce negative health effects and have a positive economic impact. In addition, they have a positive environmental impact and reduce the volume of traffic that would be on the street if everyone were using private or mass transportation.

Common carrier systems often have a legal monopoly to operate over assigned routes. They are

duty bound to pick up all passengers in common. In addition, taxicabs have to get licenses to operate as a kind of common carrier. In contrast, DRT systems use flexible rather than inflexible routes. New kinds of legislation or the amendment of older laws has been necessary to establish the legal authority for them to operate. Disputes have arisen between DRT systems and taxi companies or bus companies when DRT operators pick up passengers who have not been pre-booked. The dispute is over licensing issues. In addition, the kind of license a transport company has may also affect its tax and fuel bills.

Among the benefits of DRT systems is the provision of transportation to those who may be unable to easily obtain it. Also, there is increased passenger throughput, increased road capacity as other vehicles are not needed, and thus lessened vehicle demand. The DRT system has also proven valuable to many employers because it provides a way for some workers to get to their jobs, or to move between work sites.

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See Also: Bus Design for Accessibility; Bus Routes; Demand-Responsive Transit, Evaluation Studies of; Elderly and Disabled Travelers; Handicapped Access; Paratransit in Developing Countries; Shared Taxis.

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Diesel Engines

The diesel engine was invented in 1893 by German engineer Rudolf Diesel (who also designed a solar-powered engine that used solar-heated air). Unlike gasoline-powered internal combustion engines that ignite a mixture of fuel and air using a spark plug, the diesel engine is an internal combustion engine that compresses its fuel in order to generate heat to ignite it. As a result, it has the greatest thermal efficiency of any type of combustion engine. The diesel engine was originally designed to replace the steam engine and is the ideal type of engine for large ships, but it has also been used in construction equipment, trains, aircraft, and motor vehicles.

In the United States, diesel engines are especially likely to be used in large vehicles like trucks; diesel engines also have a long history of being used in smaller cars by European manufacturers, such as Volkswagen. Diesel engines are used in about half of the cars in the European Union (EU), where cars are typically smaller than in the United States and large vehicles like suburban utility vehicles (SUVs) are rare. Diesel engines have also been the standard engines for tractors and construction equipment ever since Caterpillar first made diesel tractors in the 1930s, and often they are used to power backup generators deployed during electrical power failures.

Diesel engines offer a number of advantages over gasoline-fueled internal combustion engines. Diesel fuel is easier and cheaper to manufacture, as it is a direct distillation of petroleum, whereas gasoline is processed in more stages. Diesel engines are one and a half times as efficient as gasoline engines, so they use less fuel and they produce less waste heat. The engines themselves are sturdier and have a much longer life span than gasoline engines, which wear out relatively quickly, especially in large equipment where the workload is significant.

The lack of an electrical ignition system makes diesel engines more reliable in damp environments like those of ships, submarines, and construction equipment. Diesel engines are generally more reliable, not requiring the use of high-voltage ignition systems or emitting radio frequencies. As a result of their efficiency, they run cooler than other engines and last about twice as long on average due to stronger engine parts, better lubrication, and less waste heat.

Further, unlike gasoline engines, which must be adapted to use other fuels or fuels with significant additive levels, diesel engines can run on synthetic diesel called biodiesel with no adjustments. Biodiesel is a diesel fuel derived from nonpetroleum sources, which many feel is more sustainable and which has the potential to be more price stable than any petroleum fuel.

The major disadvantages of diesel engines are their emissions and their response to cold weather. Diesel engines have difficulty starting in cold weather because the compression may not generate sufficient heat to ignite the fuel in the ignition chamber if the cold cylinder block and cylinder head absorb it. In diesel-powered emergency generators, this is typically overcome through the use of heaters that prevent the engine parts from becoming that cold. In very cold weather, diesel fuel can also solidify, resulting in a buildup of diesel crystals in the fuel line and eventual engine failure. This is rarely a problem with modern diesel engines except in the coldest regions of the United States, where gas stations offer winterized diesel that gels at a lower temperature.

Diesel exhaust is a serious source of pollution and has been identified as a risk factor for both lung cancer and bladder cancer, as it contains numerous toxins. The fine-particle content is especially high and dangerous, consisting of metallic abrasion particles, sulfates, silicates, soot, aerosols, and ash particulates, though modern diesel engines are much cleaner than the engines of previous decades. Even so, diesel engines produce a large amount of nitrogen oxides, which contributes to smog, and modern emissions regulations require diesel engines in on-road vehicles to reduce this quantity, typically through selective catalytic reduction. Diesel exhaust also contains sulfur dioxide, which precipitates back to the ground as acid rain.

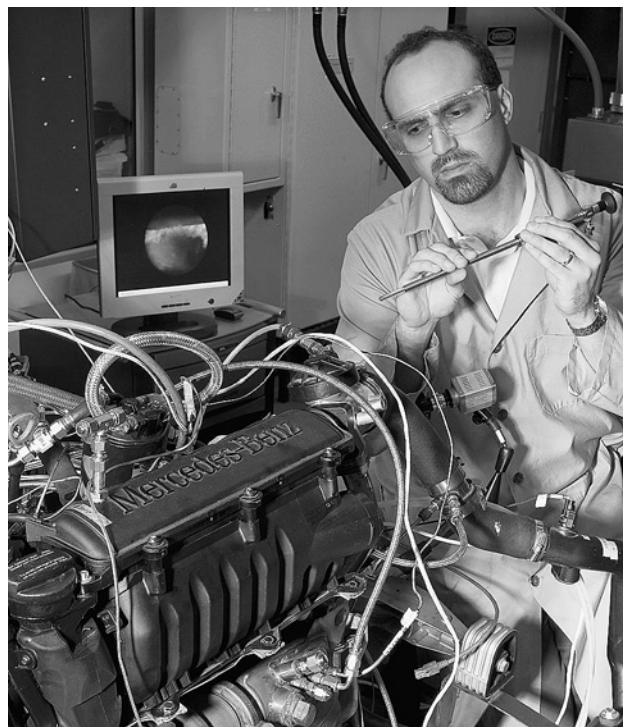
Groups regularly exposed to diesel exhaust and diesel particulate matter include railroad and mine workers, truckers, bus drivers, and children taking buses to school—the last group being one for which the U.S. Environmental Protection Agency (EPA) has shown recent concern. The Clean School Bus USA initiative is a public–private partnership seeking to reduce the exposure of children to diesel particulate matter. Exposure to diesel exhaust can lead to headaches, dizziness, light-headedness, respiratory difficulty, and nausea, with long-term exposure

leading to chronic illnesses of the heart and lungs. Eighteen carcinogens have been identified in diesel exhaust, in addition to other toxins and substances that contribute to birth defects.

Diesel locomotives and boats are considered among the worst sources of dangerous air pollution, in large part because EPA regulations for these vehicles have typically lagged behind those for road vehicles. For instance, while Tier 3 standards for nitrous oxide were eventually adopted for nonroad/off-road diesel engines in 2004 (which made them similar to the standards required for road vehicles), Tier 3 particulate-matter standards for nonroad engines were never adopted. Tier 3 standards for locomotives were not even signed until 2008 and did not take effect until 2011 or 2012. Stricter emissions standards for road vehicles have put locomotives and ships on the path to becoming the largest source of vehicle pollution. A 2006 report blamed such exhaust for 4,000 deaths a year in the United States, as well as thousands more heart attacks and asthma episodes, and a serious economic impact in the form of missed work. The 2006 Environmental Defense report on diesel locomotives, titled "Smokestacks on Rails," drew a comparison with old preregulation factory smokestacks.

Although the Occupational Safety and Health Administration (OSHA) has not established standards specific to diesel exhaust as a unique hazard, the components of diesel exhaust are included in standards related to general industry (specifically, in Part 1910 Subpart N, Materials Handling and Storage; and Part 1910 Subpart Z, Toxic and Hazardous Substances) and shipyard employment (Part 1915 Subpart Z, Toxic and Hazardous Substances). Federal inspection procedures for the Hazard Communication Standard (HCS) also touch on components in diesel exhaust. The Mine Safety and Health Administration (MSHA), which governs the mining industry, does institute regulations for diesel-powered equipment, diesel particulate matter, and diesel exhaust, while the EPA regulates emissions standards for various diesel vehicle types.

California, which is historically an early adopter of environmental regulations that are eventually adopted by the rest of the country, instituted stricter diesel regulations in 2008, requiring heavy-duty trucks and buses using diesel engines—which typically are held to more lenient standards than automobiles—to reduce their diesel particulate



An engineer at the U.S. Department of Energy's Argonne National Laboratory at work transmitting images of emissions from a Mercedes-Benz diesel engine to a computer in 2009.

matter. California has also operated the Carl Moyer Program since 1998, providing funding to retrofit engines in order to achieve better-than-required low emissions levels.

The aforementioned Clean School Bus program is one of several programs included in the EPA's National Clean Diesel Campaign (NCDC), which focuses on reducing the harmful content of diesel emissions. Clean School Bus provides strategies for school districts to reduce the emissions of older diesel buses, which are not required to follow the same emissions standards as new buses. Because of the durability of diesel engines and the budgetary concerns of school districts, these buses can remain in use for a long time, slowing the effects of emissions-standard regulations.

In addition to providing funding to reduce emissions in existing engines and to replace the oldest buses in a school's fleet, the Clean School Bus program encourages bus operators to reduce idling the motor, which needlessly contributes diesel exhaust to the atmosphere. Idling reduction is also policy in many public and private transit companies; frequently bus

stations limit idle time to five minutes, at which point if the bus does not depart, the driver must turn the engine off until time of departure. Other programs in the NCDC are the Ports and Marine program, which seeks to reduce diesel exhaust at ports for better air and water quality; Clean Construction, which provides funding to replace old construction equipment and reduce the emissions of existing engines; the SmartWay Transport Partnership, which seeks to improve supply-chain efficiency in order to reduce emissions of cargo transport and long-haul truckers; and Clean Agriculture, which provides funding to reduce emissions by agricultural equipment.

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See Also: Air Pollution, Automobiles; Biodiesel; Biofuels; Diesel Fuel Vehicles; Green Fuels.

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Diesel Fuel Vehicles

Diesel fuel, distilled from petroleum, is used to power many vehicles today, including passenger cars, buses, and trucks. While older diesel-powered vehicles produced relatively large amounts of air pollution, including particulate matter and greenhouse gases, modern diesel vehicles include a number of devices that reduce emissions and are engineered to run only on ultra-low-sulfur diesel (ULSD); this combination has reduced the amount of harmful emissions from diesel vehicles by about 90 percent.

Diesel Engines

Traditionally, diesel engines have been used in situations where a high degree of power was needed,

for instance, to power large buses and trucks, trains, large ships, and construction and mining equipment. Today, diesel engines are also commonly used in automobiles in some countries, and modern diesel engines are much cleaner and quieter than their predecessors.

Diesel engines operate by internal combustion to drive pistons connected to a crankshaft that transmits their motion to drive the vehicle's wheels. However, unlike gasoline engines, diesel engines do not need spark plugs to set off the explosions that create this motion. Instead, a diesel engine operates at a sufficiently high temperature that the air in the engine's cylinders ignites spontaneously; for this reason diesel engines are sometimes called compression-ignition engines. Rudolf Diesel, a 19th-century German engineer credited with inventing the engine that bears his name, correctly predicted that this higher concentration of oxygen would lead to greater efficiency in diesel as compared to gasoline engines.

Diesel Passenger Cars and SUVs

Diesel cars are common in some European countries but less common in the United States. However, diesel cars and sport utility vehicles (SUVs) are becoming more common in the United States, with a 24 percent increase between 2010 and 2012, from 640,779 registrations to 796,794; there are also about 6 million commercial diesel pickup trucks and vans in use in the United States. However, they still represent only about 3 percent of the U.S. market. From 2010 to 2012, the growth in registrations of diesel cars and SUVs was highest in California (55 percent), Massachusetts (45 percent), and New York (43 percent).

Three factors are believed to suppress the growth of diesel cars and SUVs in the United States: a limited range of models available, the higher cost of diesel vehicles (on average, several thousand dollars more than similar gasoline-powered vehicles), and the higher price of diesel fuel compared to gasoline (on average, about 10 percent higher, according to the U.S. Energy Information Administration). As of 2013, 27 diesel cars and SUVs were available in the United States, but this number is predicted by the Diesel Technology Forum to more than double by 2015. One reason diesel vehicles are increasingly attractive is their higher fuel economy (20 to 40 percent higher than equivalent gasoline engines), which helps

manufacturers meet increasing Corporate Average Fuel Economy (CAFE) standards.

In 2012, over half (54.9 percent) of vehicles registered in the European Union (EU) were diesel powered, a slight decrease from 2011 (55.2 percent), but a substantial increase from 2000, when diesel vehicles represented 31 percent of new passenger cars; since 2006, diesel-powered vehicles have represented more than half of all new passenger vehicles registered in the EU.

In 2007, the EU adopted a comprehensive strategy to reduce carbon dioxide emissions, setting a standard for new diesel vehicles of 130 grams of carbon dioxide per kilometer by 2012, and began enforcing mandatory emissions targets in 2012; if a manufacturer's fleet does not meet the target, it must pay a premium for each new car registered. The emissions standards have successfully reduced average carbon dioxide emissions from new cars (all fuels)—132.2 grams of carbon dioxide per kilometer, down from 135.7 grams per kilometer in 2011. Looking just at diesel cars, average carbon dioxide emissions were 131.6 grams per kilometer in 2012, down from 134.7 in 2011, and a substantial reduction from 2010, when the average was 160.3 grams per kilometer.

Diesel Trucks

Diesel trucks are major contributors to pollution from diesel exhaust. In January 2001, the Environmental Protection Agency (EPA) finalized the Heavy-Duty Highway Diesel rule, setting emissions standards for heavy-duty diesel trucks and buses to take effect in 2007. To meet these requirements, petroleum refiners began producing ultra-low-sulfur diesel in June 2006; ULSD reduces sulfur content in highway diesel fuel by 97 percent—15 parts per million (ppm) versus the old standard of 500 ppm. In addition, diesel vehicles equipped with the advanced pollution control technology necessary to meet the 2007 standards came onto the U.S. market in fall 2006, and these vehicles run only on ULSD. Trucks with the new pollution control devices and running on ULSD produce 90 percent less pollution than previous models. The 2007 standards were projected to reduce particulate matter in exhaust by 110,000 tons per year and to reduce nitrogen oxide emissions by 2.6 million tons per year. Older diesel engines can also run on ULSD, and as of 2010, only

ULSD has been available in the United States as a highway diesel fuel.

Diesel School Buses

Protecting children from diesel exhaust is a particular concern because children have a faster breathing rate than adults, taking in about 50 percent more air per pound of body weight than do adults, and because many school buses are diesel powered. However, children's exposure to harmful emissions has been greatly reduced due to improvements in technology and more stringent regulations: the EPA estimates that school buses built today are 60 percent cleaner than those built before 1990.

The EPA's Clean School Bus USA Program, launched in 2003, offers incentives to reduce emissions from school buses by providing information about retrofit technologies (e.g., particulate matter filters, oxidation catalysts) to make old buses run cleaner, providing funding and incentives to replace or retrofit diesel buses, and providing educational materials and tools to help calculate potential emissions reductions and promote practices that reduce emissions, such as reducing bus idling, switching to cleaner fuels (for example, biodiesel), and using the cleanest buses in a fleet on the longest routes. As of 2012, an estimated 45,000 school buses serving over 3 million students were using technologies that reduce diesel emissions.

Air Pollution

Diesel engine exhaust is made up primarily of gases and soot. The gases include carbon dioxide, carbon monoxide, sulfur oxides, nitric oxide, nitrogen dioxide, and polycyclic aromatic hydrocarbons and other hydrocarbons, while soot is particulate matter including carbon and other organic materials and metallic compounds. Exposure to diesel engine exhaust is associated with elevated rates of many health problems, including heart disease, cancer, asthma and other lung conditions, and eye irritation.

Most exposure to diesel engine exhaust comes from breathing, and exposures are highest among those working around automobiles, trucks, and heavy machinery (drivers, toll collectors, garage employees, etc.), and some farm workers and miners. People living and working near major highways may also experience high exposure, as may children who ride diesel-powered buses to school.

There are many complications involved in studying the health effects of exposure to diesel engine exhaust—the level of exposure is difficult to measure, other exposures may produce similar effects, the effects of exposure may not be apparent for years, and changes in diesel technology mean that the effects of a given amount of exposure in years past may not be equivalent to the same amount of exposure today. However, the International Agency for Research on Cancer of the World Health Organization classifies diesel engine exhaust as a human carcinogen (cancer-causing agent), while the EPA classifies it as a potential human carcinogen. Lung cancer is the disease most convincingly linked to exposure to diesel engine exhaust, with most studies involving occupational exposure (truck drivers, railroad workers, miners, etc.). Some studies have also found relationships between exposure to diesel engine exhaust and cancers of the blood, stomach, bladder, esophagus, and larynx; however, the evidence is not conclusive.

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See Also: Air Pollution, Automobiles; Air Pollution/Air Quality; Biodiesel; Bus Engines; Diesel Engines; Light-Duty and Pickup Trucks; Trucks.

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Disabled Driving and Vehicle Modifications

Disabled drivers who have a vehicle of their own are more self-reliant than those having to wait for the availability of another person to drive them, and this can have a significant impact on quality of life. Careful examination of the ability of people with physical abilities to drive personal automobiles has been taking place for many decades—almost as long as attempts have been made to create self-driving cars, which, of course, are designed to need no input from designated drivers at all. These examinations have incorporated examination of the interaction between new technologies and designs and the types of physical disability involved.

Increasingly, the technology embedded in personal therapeutic devices is able to bring the person involved to the level of being able to operate an unadjusted personal vehicle. However, the variety of possible disabilities (which often, of course, come in combinations) and their interaction with the types of personal automobiles and their devices is so great that it can be dangerously reductive to try to make simple principles and rules. Input devices, in particular, have moved to become voice activated or responsive to contact in ways that are nonstandard in previous forms of vehicle control, and these systems do not require the standard driving activities at all. New generations of video games have regularly featured the control of complex machines and vehicles through a variety of joystick and push-button controls and, while it is problematic to project video game representations of life onto the real world, these designs are being introduced into vehicles controlled by disabled drivers. Finally, since it has become evident that vehicles are more safely guided by autopilot systems than by human beings in most circumstances, the degree and nature of any disability has become less relevant as technology

replaces human agency, within the constraints of what is acceptable in society.

Social Norms

To a certain extent, the degree to which vehicles for disabled drivers have become prevalent and acceptable in different countries depends on the attitude of society as a whole toward disability and to different forms of society. Although societies have generally become more internationalized and global norms have started to replace local norms in a number of cases, it nevertheless remains the case that most societies have a definite response or set of responses to an issue such as personal disability. The possible responses can vary along a scale that, at one end, now less commonly seen, requires people to be sequestered at home because of some form of societal taboo, to the other end at which all individuals are fully integrated into the public and private spheres of society. Plainly, this scale is correlated with the ability of disabled people to obtain the modified equipment they need and use it when required.

An additional societal dimension to consider is the attitude toward the welfare state. Since many people with disabilities have difficulties obtaining well-paid work, they may face financial hardship unless they are supported to some extent by the state, since the state is generally required to make transfers universal rather than on a preferential or partial basis, which is what occurs with charitable giving. The state may provide a modified vehicle directly or at a subsidized price or else offer help in modifying standard vehicles according to specific needs. State provision is likely to be integrated with the system of traffic safety and regulations and, hence, to conform directly to legal and insurance requirements. This may not be the case with privately provided modifications.

Forms of Modification

Vehicles are customarily operated with the hands, for the steering wheel and dashboard controls, and with the feet, for using the pedals. Additionally, of course, vision is required to observe conditions through the windshield and windows and also to monitor the various mirrors employed. Nearly all of these requirements can be adjusted or removed through the use of engineering. Hand controls can replace some foot controls and vice versa, while use

of mirrors can assist people with limited neck or spine mobility. Some vehicles make it convenient for wheelchair users to gain access to the vehicle, sometimes as a passenger but also as a driver. This feature is now a standard for at least some models in the overall range for most major automobile manufacturers. The Hungarian company Kenguru makes an electric vehicle specifically designed for wheelchair users. The Kenguru car is just large enough to accommodate a wheelchair of reasonable size and has a rear hatchback door to permit the wheelchair user to enter from the rear and then drive the vehicle directly. The vehicle is powered by electricity and environmentally friendly, which makes it more convenient for urban living than a rural setting, but this situation is changing.

Another innovation is the hand control system. This may be installed in the vehicle permanently or kept as a portable feature, enabling a disabled driver to modify any existing vehicle or to share a vehicle with an able-bodied driver. The device may be configured to permit the driver to drive with limited or no use of the feet and use a joystick control to activate not just the steering wheel but also lights, windshield wipers, and other important features. These systems are made possible by the increasing use of computers and electronic components in contemporary automobiles—most vehicles of previous generations would be too difficult or too expensive to modify. Hand controls make it possible for people who are senior citizens, suffering from severe arthritis, or without hand or leg functions to continue driving. However, while it may be possible in due course for self-driving cars to be used to transport people in nearly any condition, there are some conditions or degrees of severity that are unsafe for driving because of the inability to control the vehicle safely or because the condition or the medication being used to treat it compromise the judgment necessary to deal with traffic.

Practical Issues

Driving involves more than the control of the car. It is also necessary to obtain insurance and to ensure that the vehicle is maintained at a level that is safe and that conforms to the laws. It is also necessary to have a valid driver's license and for the disabled this usually requires the assistance of a medical doctor, which may be an additional cost. However, in the developed world, most large commercial or

government facilities make provision for a number of designated parking spaces close to the entrance, and these may be larger than standard size so as to facilitate loading and unloading wheelchairs. In any case, most disabled drivers find that it is usually required to plan ahead carefully when making a journey to a previously unvisited destination and to allow more time for contingencies than would be required for able-bodied drivers.

Disabled drivers' interactions with the police and other officials might also be more complex. Disability rights groups around the world lobby government and relevant agencies to try to obtain better terms and conditions and to amend laws that may be discriminatory and that technology and societal change have rendered redundant. This is part of a broader campaign for equal treatment and access.

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See Also: Automobile Drivers, Disabled; Automobile Drivers, Elderly; Elderly and Disabled Travelers; Elderly Driver Safety Issues; Handicapped Access.

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Distracted Driving

Deaths caused by automobile accidents have been a major problem since the beginning of automobile transportation. Excessive speeds, intoxicated drivers, impatient drivers, and other causes—including distracted driving—have contributed

to a significant annual automobile accident death toll. Distracted driving is anything that distracts a driver from focusing completely on driving the vehicle. Historically, eating, drinking a beverage, lighting a pipe or cigarette, grooming, talking, arguing, children, pets, reading maps, or romantic exchanges between the driver and the front seat passenger have caused distracted driving.

In more recent decades technological developments have added to the list of distractions, including looking at directional devices; watching TV; manipulating a radio, CD player, or MP3 player; or other causes of inattention. All of the distracting devices and behaviors and more have contributed to automobile accidents. Other distractions include visual distractions that cause the driver to take his or her eyes off of the road and/or manual distractions that occur when the driver takes one or more hands off the steering wheel.

Since the advent of mobile phones, distracted driving caused by attending to a mobile phone or other device has been increasing. Texting, cell phones, in-car phones, and other distractions are cognitive distractions that cause the driver to fail to focus on his/her driving. Any distraction causes the driver to fail to focus on driving, which then endangers the driver, passengers, pedestrians, the vehicle, other vehicles, and property. Cognitive distractions caused by texting or by receiving or making mobile phone calls are the result of massive changes in technology. These changes have not been accompanied by increases in disciplined driver safety practices.

Effects

The Centers for Disease Control and Prevention (CDC) has reported that nine or more people are killed and over 1,060 are injured every day in the United States because of distracted driving. Accidents resulting in damage, injury, and death and caused by distractions from texting or phone usage have been increasing. Over 5,400 people were killed and 448,000 injured in driver-distracted wrecks in 2009, according to the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department of Transportation. These figures represent 16 percent of all fatal crashes and 20 percent of injuries from accidents.

Texting has been rapidly adopted by teenagers in U.S. society, tempting many to text while driving. A study by the American Automobile Association



Distracted driving is responsible for more than nine deaths and 1,060 injuries per day in the United States. In 2009, fully 16 percent of all fatal crashes and 20 percent of all injuries from automobile accidents were attributed to distracted driving. All U.S. states have adopted laws to prohibit certain kinds of cell phone usage or texting.

(AAA) Foundation for Traffic Safety found that teenage drivers are the most distracted of all drivers. A study reports that they are distracted as much as 25 percent of the time by electronic communications devices. As a result, teens are more likely to be involved in a distracted-driver accident while texting than are older groups. The NHTSA estimates that 16 percent of teenagers involved in a fatal accident were distracted by texting. Studies have shown that a third of American drivers have either read or sent a text message or e-mail while driving in the 30 days prior to the time they were surveyed.

Drivers distracted by hand-held devices are four times more likely to be involved in vehicle accidents than drivers who do not use them. Texting and cell phone calling are the principal causes. The reason, of course, is that looking at the hand-held device to text or to call takes the driver's eyes off of the road for an average 4.6 seconds. At speeds over 55 miles per hour, this is like driving blind for the length of a football field (100 yards).

Using a cell phone and driving impairs the cognitive reactions of the driver. A University of Utah study found that the driver impairment was as great

as if the driver were intoxicated with a blood alcohol content of 0.08, which is the common legal limit. The National Safety Council has reported that use of headsets is not safer than handling a cell phone or other device. One reason for the lack of greater safety from using a headset is that talking on the phone while driving reduces the brain's engagement with reading and responding to road conditions by 37 percent. Text messaging is an extremely dangerous driver distraction because it distracts visually, manually, and cognitively.

In 2010 distracted driver crashes killed 3,267 people and injured 416,000. In 2011 there were 3,331 people killed in driver-distracted crashes and 387,000 were injured. Two solutions that are being applied to this highway safety problem are education of Americans about the dangers posed by distracted driving and laws to prohibit their use while driving. The laws are like the laws prohibiting drinking alcoholic beverages and driving.

Laws

The problem of distracted driving due to cell phones and texting has led to the adoption of numerous

laws. The Federal Motor Carrier Safety Administration (FMCSA) has issued regulations prohibiting the use of cell phones and texting for bus and truck drivers engaged in interstate transportation. All of the states have adopted laws to prohibit certain kinds of cell phone usage or texting. Some states have adopted laws that prohibit the use of cell phones—including those that are hands free—for bus drivers, and especially school bus drivers. Others prohibit their use by teenagers, novice drivers, and others, including adults.

In some states novice drivers are forbidden to use a cell phone while driving. Some states prohibit all texting while driving. In some states these are primary enforcement offenses, that is, the driver may be cited for using a cell phone without being charged with any other traffic offense. Many localities have adopted local ordinances to prohibit electronic devices that cause driver distraction. The overall solution for most safety experts lies in a combination of regulatory policies and safety training.

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See Also: Automobile Accidents and Prevention; Impaired Driving; Traffic Laws and Enforcement.

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Dredging

Both natural waterways, such as bays and rivers, and man-made waterways, such as canals and harbors, are often too shallow for certain deep-hull vessels to navigate safely. In these instances, it may become necessary to artificially deepen the waterway through a process called dredging. A body of water

is dredged by scraping sediment from the bottom using a variety of methods. Through this process, material is removed from the waterways; this allows ships to safely use the body of water without running the risk of hitting bottom. Dredging is not only conducted for navigational purposes. There are also environmental purposes for dredging, such as the removal of toxic materials or objects from a body of water. Dredging may also be used to replenish sand on some public beaches to combat coastal erosion. Despite its positive uses, its negative environmental impacts are especially concerning. In particular, dredging disrupts the natural ecosystems of both the dredged bodies and the disposal site.

How It Works

The primary economic reason dredging is needed is to maintain maritime industries. Due to a variety of processes including natural erosion, fine particulates in the form of silt gradually wash downstream. Over periods of time, the silt gradually fills bodies of water, causing the bodies to eventually become shallower or even creating small islands in the waterway.

It is widely acknowledged that without precaution, dredging can be greatly environmentally damaging. For this reason, disposal of dredged materials is highly regulated by the U.S. Environmental Protection Agency (EPA). The EPA lays out three key criteria that must be met before dredging material may be disposed of: (1) the party must demonstrate a concrete need for dredging, (2) there must be a comprehensive analysis of all reasonable dredging methods and disposal sites for the dredged material, and (3) testing must be performed to ensure that dredged material to be placed will not harm the environment of the dump site.

While there may be a great variety of equipment and highly specialized techniques, all dredging can be put into one of two categories: hydraulic and mechanical. Neither type is more efficient or safer in every context. Hydraulic dredge systems use pumps and are typically mounted on a barge. Once the dredged material is pulled into the system by the pump, it is moved via a pipeline to either the barge or a nearby disposal area. Mechanical techniques remove dredged materials from the body of water in question by using machinery. This is typically done with a clamshell bucket (also known as a grab dredger), but bucket ladder dredgers are also commonly used. Mechanical techniques may be

preferred when there is risk of airborne emissions from the dredged material, such as when said material is particularly toxic or volatile.

Environmental Impacts

As mentioned, dredging may have either positive or negative environmental impacts. Unfortunately, the net impact of dredging is likely more negative than positive. Environmentally positive dredging may be used to reduce exposure of natural and human contaminants that have been brought into a body of water by vessels using it; this type of dredging is called “environmental dredging.”

In the United States, all dredging is overseen by the EPA and the U.S. Army Corps of Engineers, and both agencies pay more attention to the dredging that poses potential negative impact. The potential negative impacts of dredging are complex and varied; in fact, the complexity of the negative impacts often obscures their very existence. The contents of sediments are of major concern regarding the environmental impact of the potential dredge, as sediments in and around cities and industrial areas are often contaminated with a variety of toxic substances. Considering this likely contamination, disposal of dredged sediments from urban areas often amounts to toxic dumping. Thus, dredged materials cannot be put in oceans or other bodies without a permit from the U.S. Army Corps of Engineers, using the above-mentioned EPA criteria.

The potentially toxic artificial contents of a dredge determine most of the negative environmental impact. The release of toxic chemicals from passive sediments can be made active when introduced to the water column. These passive elements include heavy metals and even materials that have been long outlawed, such as DDT. Once reintroduced to ecosystems via the water column, these toxins can once again be consumed by food animals and thus impact humans.

Apart from the introduction of toxins, additional negative impacts to the ecosystem include short-term disturbances in the quality and condition of the aquatic ecosystem. Regardless of intent or methods of dredging, all dredging activity releases suspended sediments into the aquatic ecosystem, and such releases occur over the entire course of the dredge process: excavation, transport of dredged material, and disposal of dredged material. Introducing materials into the ecosystem has the



Mechanical dredging with a clamshell bucket or grab dredger on the Yarra River in Melbourne, Australia, in 2008. Mechanical dredging may be preferable when handling toxic or volatile materials in sediment that could become airborne.

dual effects of reducing the ability of light to penetrate the water and physically altering water flow. Reduced light penetration can result in interfering with the metabolic processes of plants and behavior of aquatic animals.

Altered water flow interferes with animal life by inhibiting feeding mechanisms and trapping debris in gills, especially in younger fish that are incapable of escaping the dredge area; altered water flow can also have similar effects on plant life. Factors that determine suspension issues include the quality of sediments being dredged, the method of dredging and disposal, the water conditions of all ecosystems encountered, and other existing water quality and characteristics.

As with the toxic hazards of dredging, the suspension-based dangers of dredging can be made significantly less hazardous if proper precautions are taken. Dredging is less dangerous when it is performed in man-made bodies, such as locks or dock basins. Luckily, suspension issues typically are limited to an area of less than 0.62 mile (1 kilometer) surrounding the dredge area and last for less than one week in those areas. Likewise, turbidity problems typically last only for the duration of the dredge.

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See Also: Canals and Locks; Environmental Impacts; Harbors, Environmental Issues; Harbors and Ports, Administration and Operations of; Water Pollution.

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populated states such as California, Florida, New York, and Texas have the highest number of traffic accidents, statistics in the United States show that the number of accidents is slowly decreasing, possibly due to more effective driver education.

Approximately 196.5 million people living in the United States possess a driver license. The driver license in the United States serves two purposes. First, it certifies that an individual has learned how to operate a motor vehicle safely and that they know how to read road signs and follow state and federal laws that apply to driving. The driver license in the United States also serves as a form of photo identification and proof of residency within a particular city, county, or state. Even if someone is not a frequent driver, the driver license serves as the most common form of government-issued identification for employment purposes, along with a social security number. For this reason, most young adults in the United States strive to acquire their driver license as quickly as possible. People who move from one state to another must apply for a new driver license issued by that state; a license is not issued without passing a written test, a road test, or both. The elderly, as well as people who have not driven for a long time due to medical reasons, must also retake a written test, a road test, or both prior to renewing their license.

History

Prior to the 20th century, European and American roads were designed for horse-drawn or pedestrian traffic, and horse-drawn carriages remained the more practical form of transportation. Little has been recorded about the actual training of horse-drawn coach drivers; carriage drivers and horseback riders often learned how to ride and operate horse-drawn vehicles from their parents, friends, or professional trainers. The rules of driving a horse-drawn vehicle did not vary much from state to state, let alone nation to nation. For the most part, if a city or state required a license for carriage drivers or horseback riders, it was to establish ownership of the carriage, horse, or both, rather than whether the person received state-approved training to ride or drive.

In the 19th century, European and American inventors developed a variety of steam-, electric-, and gasoline-powered vehicles that did not require a horse to pull them. Not many of these automated vehicles existed, and only the very wealthy could afford them. As the wealthy were subject to no

Driver Licensing

The estimated number of automobiles on the road around the world ranges from 650 million to over 1 billion. This means that at least 650 million human beings have the ability to drive. As public transportation does not serve all locations equally, and as not all infrastructures support train, tram, bus, bicycle, or pedestrian traffic, it has become essential for individuals—particularly in the United States—to learn how to drive. As the number of cars on the road increases, the occurrence of traffic accidents also increases. While more heavily

restrictions on how they could ride horses or carriages—especially in Europe—they received little or no training on how to drive these new vehicles. The presence of these noisy automated vehicles, which traveled at unpredictable speeds and frequently broke down, frightened horses and caused accidents. Though a horse had the potential to trample a pedestrian if the driver was distracted or driving too fast, a horse's first instinct is to stop if approached by a smaller creature; the rider or driver, rather than the pedestrian, was more likely to sustain injuries in such an event. With the advent of automated vehicles, driving alongside horse-drawn vehicles and pedestrians, a single distracted human driver had greater potential to injure and kill others on the road.

The concept of a driver license for automobile owners began in Germany. The Grand Ducal authorities of Mannheim, Germany, issued a license to the inventor of the modern automobile, Karl Benz, in 1888. Citizens of Mannheim complained about the noise and smell of his *Motorwagen*, so Benz requested and received written permission to drive the vehicle on public roads. This type of license, however, did not establish Benz's driving aptitude.

In 1903, Prussia became the first state in Germany to require mandatory licensing and testing for automobile drivers. A driver could not receive a license to drive a motor vehicle in Prussia without taking a driving test to confirm the ability to operate the vehicle in a safe, responsible manner. In 1910, the German imperial government mandated driver licenses on a national scale, establishing the first national driver education program and a series of tests that would serve as a model for other nations.

In the United States, there is some debate as to which city or state was the first to mandate driver license testing. In 1899, a New York City ordinance stated that a driver of a steam-powered car must be a licensed engineer. In 1903, Massachusetts and Missouri issued the first state driver licenses but required no test of the driver's aptitude.

As ownership of automobiles increased after the introduction of the inexpensive Model T Ford, the number of injuries and deaths caused by motor vehicles in the United States increased dramatically. In 1907, the *New York Times* published an article titled "Better Auto Laws Are Now Needed" in which automobile experts voiced their concerns about the accidents caused by careless, untrained drivers.

Legislators reviewed French and German laws as models but could not mandate a national driver education program due to constitutional rights granted to each state to develop their own education system. In 1908, Rhode Island became the first state to issue driver licenses based on the results of a driving skills test. In 1913, New Jersey became the first state to require that all drivers pass a mandatory examination before receiving a license. This state-mandated exam included a road test and a written test.

By the 1930s, nearly three-quarters of households in the United States owned a car. At the same time, while high schools began to develop driver education programs, many states still did not require a test of driving skills prior to issuing a license to drive. It was customary for the state to charge new drivers 25 to 50 cents in exchange for a driver license. The last state to require drivers to pass a driving exam was South Dakota in 1959. While there are some small variations in traffic laws from state to state, they do not prevent any trained, licensed American from driving across the country. Americans who wish to drive in other countries must obtain an international drivers license, but this may be insufficient preparation to drive in countries with unfamiliar traffic conditions.

Components of Driver Licensing

In the United States, each state has a department of motor vehicles that issues driver licenses and arranges written and practical driving tests. Minors in each state can apply for learner's permits that allow them to drive with a licensed driver in the car, for limited hours and distance each day. In some states there are minimum age requirements for obtaining learner's permits, taking driver education training, and qualifying for official driver licenses. Many states require the successful completion of a driver education course before a young driver can get behind the wheel of a car. Minors in rural states who have experience operating farm equipment, such as tractors or harvesters, often have an advantage over others, as one can acquire permission to drive farm machinery as young as 12 years of age.

In many states, the department of motor vehicles provides an information booklet to new drivers about traffic laws, road signs, the significance of straight and dotted lines on the roads, driving under different weather conditions, speed limits, and laws about driving under the influence. New

drivers must memorize all of the information in the state-issued booklet in order to pass the written test, which in most states is now administered by computer. New drivers must schedule an appointment with the department of motor vehicles to take their written driving test; the test is proctored and graded on site, so that people can get their results that day. It is necessary to pass the written test in order to receive a temporary license or a learner's permit. Some people take online courses to prepare for the written test.

First-time drivers are also required to pass a practical driving test. While the departments of motor vehicles in each state proctor the actual driving tests, they do not provide cars, nor in most cases do they provide driver education. New drivers must find someone who will sit behind the wheel with them and teach them how to drive. While some people learn how to drive a car from their parents, siblings, or friends, others have the opportunity to take driver education classes through their high school. Others take driving lessons from a driver education school. These formal lessons take place in a special car fitted with dual controls, with pedals on the passenger side for the instructor in case the student drives too fast or slow. In the United States, most instruction on learning how to drive automobiles takes place in cars with an automatic transmission, though students can request instruction on a stick-shift car if they wish. Students learn skills such as acceleration and braking; how to watch and anticipate the actions of other drivers on the road; how to make turns; how to get on and off freeway ramps, change lanes, and parallel park; and how to drive in city, residential, and rural traffic. Students may take as many lessons with the instructor as necessary until the instructor and student feel prepared enough to schedule the road test at the department of motor vehicles.

If students fail either the written or practical test, they have the opportunity to retake either exam as often as they wish. As the department of motor vehicles charges a fee for each exam, however, there is motivation to master skills prior to taking the exam.

Impact of Driver Licensing

Teenage drivers are most at risk for getting into accidents due to inexperience and impulsivity. According to various reports, driver license training leads to early licensing, but there is little or no evidence that it reduces the increased crash risk for

beginning drivers. At the same time, statistics show that the number of car accidents, particularly those caused by alcohol abuse or other distractions, have decreased for all age groups. Driver license training plays a major role in educating beginning drivers about seat belt usage, drunk driving laws, and state laws that may ban cell phone use while driving.

Senior citizens, because of failing eyesight, weakened reflexes, and mental deterioration, are also at increased risk for getting into car accidents. For this reason, many states have implemented mandatory driver license retesting on one's 65th birthday. Part of the driver license application and renewal process for drivers of all ages is an eye exam. If a person must wear corrective lenses in order to read the chart for the eye exam, most states will indicate on the person's driver license that corrective lenses are required for driving. If a senior citizen fails the eye exam, even with corrective lenses, it is not likely that his/her license will be renewed.

It is against the law to drive any motor vehicle, whether owned or rented, without a license in the United States. Each state determines its own penalty for driving without a license, depending on the reason for police intervention. For illegal immigrants driving without a license, the penalties can include deportation. Most state departments of motor vehicles do not ask for a birth certificate when one fills out a driver license application, participates in driver license training, or takes a road test. In culturally diverse areas of the United States, driver education and department of motor vehicle forms are available in the major languages spoken in those areas. Providing driver education, forms, and tests in the languages of various immigrant groups retrains those from other countries who drove under different laws, drove under no laws, or had never driven before. Mandatory written and road tests to acquire a driver license ensure that all people within a country understand road signs, comply with speed limits, communicate effectively with other drivers on the road, and avoid distractions while driving in order to avoid accidents.

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See Also: Automobile Accidents and Prevention; Driver License Rates; Motorcycle Safety; Speed Laws and Enforcement; Traffic Laws and Enforcement.

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Driver Licensing, Commercial

Commercial drivers are usually truck or bus drivers. They engage in hauling cargo or passengers over short to very long distances. In the United States, Canada, and other countries, the driving of commercial vehicles requires a special commercial driver's license (CDL).

Early versions of a driver's license were developed in Chicago and New York City. Chicago required all drivers of a motorized vehicle to pass an exam before driving. New York City adopted an ordinance that required steam-powered cars to be driven by a licensed engineer. In 1903 Massachusetts and Missouri issued driver's licenses, but no examination requirements were necessary. For practical purposes, the earliest licenses were identification cards. Many states in the 1930s and 1940s required only the payment of a small fee to get a driver's license. In some cases these could be acquired by mail.

Widespread adoption of driver's license laws to operate a car, truck, bus, or other vehicle began in the 1920s as the number of drivers increased at an enormous rate. With the increases in cars and drivers on the roads, motor vehicle accidents also increased. Many accidents were the fault of inexperienced or careless drivers who were driving more powerful vehicles. At higher speeds, inexperienced drivers or foolhardy drivers were increasingly a danger to themselves and to others as they drove at high speeds or recklessly. To slow or prevent the

rising increase in wrecks that damaged property and killed or injured people, acquiring permission to drive on the public roads was mandated.

As safety concerns increased, public pressure developed to mandate that drivers demonstrate driving competency. Rhode Island instituted the first program for testing drivers before issuing them a driver's license in 1908. By 1913 New Jersey was requiring drivers to pass an examination of driving abilities and also knowledge of highway laws and safety. Other states slowly followed suit.

Prior to 1986 a license to drive a bus or a large tractor-trailer truck or some type of longer combination vehicles (LCVs) varied from state to state. In the District of Columbia and in many states all that was necessary for a commercial driver was a license to drive an automobile. Many states did not have a classified licensing system, nor did they have a system for skills testing the driver applicant on the type of vehicle (personal or commercial) that would be like the one they would be driving.

During the era prior to 1986 many truck drivers were not trained to drive the "big rigs" being introduced to haul larger loads on the Interstate Highway System. As a consequence of their insufficient training, many drivers had avoidable accidents, resulting in property losses, injuries, and vehicular deaths. To deal with the highway damage and slaughter, Congress passed the Commercial Motor Vehicle Safety Act of 1986, which was signed into law by President Ronald Reagan on October 7, 1986. The law requires all drivers of vehicles that have a gross vehicle weight rating (GVWR) of 26,000 pounds (11,793 kg), haul hazardous materials, or carry more than 16 passengers to have a commercial driver's license (CDL). The law also requires tow truck operators to be licensed.

The main purpose of the act was to ensure that those driving trucks, buses, tractor-trailers, or other vehicles that qualify as commercial motor vehicles (CMVs) are qualified and responsible drivers. The act engages in cooperative federalism. The states test drivers and issue licenses, but the minimum standards are set by the Department of Transportation. Only if an applicant for a CDL has been tested by the state in an approved testing facility is a state able to issue a CDL. The examination includes both a written exam and a practical test.

Since April 1992 all drivers of a CMV have had to have a CDL or be in violation of the federal law. The

testing standards have been developed by the Federal Highway Administration (FHWA) and apply to all drivers of Class A trucks (GVWR of 26,001 pounds or more), Class B trucks (GVWR of 26,001 or more) that tow a vehicle not in excess of 10,000 pounds, and Class C trucks that haul hazardous material or carry more than 16 passengers.

While the federal Commercial Motor Vehicle Safety Act of 1986 sets minimum standards for a CDL, states may add more requirements they deem necessary for public safety. For example, in New Jersey a bus, van, or limousine driver must have a CDL in order to legally drive 8 to 15 passengers, which is less than the 16 passengers mandated by federal regulations. In New York a CDL is required to drive a school bus or other passenger transport vehicles listed in Article 19-A of the New York Vehicle and Traffic Law.

The Department of Transportation has set 21 as the minimum age for drivers with a CDL to operate a commercial motor vehicle in interstate commerce. However, some states allow drivers between the ages of 18 and 20 to get a CDL. Their CDL allows them to drive only within their state until they reach the age of 21, when the CDL automatically converts into a federally sanctioned license for interstate driving.

Since 2013, obtaining the CDL has become a strenuous process, with both a written test and a three-part skill exam. The increasing requirements mean that drivers need a proper education in order to pass the CDL exams. For example, the Alabama CDL rule book is 159 pages in length. The division of motor vehicles (DMV) in each state has its own unique set of application procedures and training program regulations. Some states provide training, whereas other states depend upon third parties to provide the training for the CDL exam, all of which may cost the prospective licensee significant fees.

In addition to the road and vehicle operations examinations, a CDL applicant must also pass a medical examination. The medical form must be completed by a physician licensed in the United States. In addition, a doctor of osteopathy (D.O.), licensed physician assistant (P.A.), advanced practice registered nurse, or chiropractor who is clinically competent to perform the medical examination can conduct the medical examination and complete the applicant's medical form. The medical

form must be submitted to the applicant's DMV along with his/her original application. The medical form may not be more than two years old from the date of application. In some states school bus drivers aged 65 and older must submit a new medical form annually. Federal regulations mandate alcohol and drug testing for CDL drivers. All states have regulations for handling those found engaged in driving under the influence of alcohol or engaged in substance abuse.

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See Also: Buses; Driver Licensing; Passenger Van Safety; Truck Inspections and Vehicle Licensing; Trucks; Trucks; Safety Issues and.

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Driver Licensing Rates

Changes in the number of drivers impact the demand on transportation infrastructure, congestion, pollution, and transportation system and energy demand. While the majority of adults in the United States are licensed drivers, differences in rates of licensure exist between people of different ages, race/ethnicity, and immigrant status, primarily as a result of household income and other socioeconomic differences.

Driver licensing in the United States has not always been as pervasive as it is today. In 1950,

less than half of the population was licensed to drive, but as automobiles became less expensive to own and operate, public policies developed urban infrastructure conducive to vehicular transportation, and as women became more heavily involved in the labor force, licensure rates increased substantially and the growth in the number of drivers in percentage terms exceeded the growth in the total population overall up until the first decade of the 21st century.

In 2010, there were 679.6 licensed drivers per 1,000 people (up from 407.9 in 1950). Because of differentials in licensure rates among race/ethnic groups, continued population growth will increase the number of drivers, but the rate of growth may continue at a slower pace as the United States becomes more racially/ethnically diverse.

Differences by Gender and Age

According to the 2009 National Household Transportation Survey, 88 percent of the adult population was licensed to drive. Historically, women were less likely to drive than men, but as women became more involved in the labor force, the gap in licensure between men and women closed so that by 2009, 90 percent of all men and 85 percent of all women were licensed to drive and over 90 percent of both men and women between the ages of 35 and 60 were licensed to drive. Only in the oldest age groups do gaps in licensure rates of over 10 percent remain—primarily as a result of changes in women's roles and generational attitudes.

The next several years will see a change in the characteristics of elderly drivers as the baby boom generation (those born between 1945 and 1964) reach retirement age. In 2009, 64 percent of non-drivers were younger than age 25 or aged 65 years and older. While overall 60.9 percent of nondrivers were women, 76 percent of nondrivers aged 65 years and older were women.

Differences by Race/Ethnicity

At 91.3 percent, non-Hispanic whites have the highest driver licensure rates compared to other racial/ethnic groups, and non-Hispanic blacks and Hispanics have the lowest licensure rates at 77.9 and 77.6 percent, respectively. All other groups have rates closer to non-Hispanic whites (at 86 percent). The lower licensure rates for non-Hispanic blacks and Hispanics are primarily a result of lower

incomes as well as having a large proportion of the population living in central cities where other forms of transportation are available or a result of having a significant proportion of immigrants (for Hispanics). Although lower relative to non-Hispanic whites, the differences in licensure between men and women for non-Hispanic blacks are less than 4 percent overall.

Among the two groups with relatively large immigrant populations, non-Hispanic Asians and Pacific Islanders and Hispanics have larger gaps in licensure between men and women (7.3 and 15.1 percent, respectively). In fact, licensure rates among Hispanic males are similar to those of non-Hispanic whites (at 86 percent overall and over 90 percent for all age groups from ages 30 to 64). Since these are two of the fastest growing groups in the United States, increases in licensure for Hispanic and Asian women will have a significant impact on growth in the number of drivers in the United States in the future.

Immigrant Status

The longer immigrants live in the United States, the more likely they are to become drivers. This change in status can be understood as one indicator of assimilation to the dominant culture. Still, rates of licensure are lower for immigrants who have lived in the United States for a long period of time. Overall, 81.5 percent of those born outside the United States were licensed to drive in 2009 (compared to 89.9 percent of the population born in the United States). Women immigrants have the lowest licensure rates. In fact, at 90.1 percent, male immigrants have licensure rates equal to that of the U.S. born (91.5 percent). Only 73.6 percent of foreign-born women were licensed to drive in 2009, compared to 88.3 of U.S.-born women.

Income Differences

The percentage of people licensed to drive increases with income. There is a symbiotic relationship between income and driving. An individual with a license to drive and access to an automobile is able to access a wider variety of jobs within a larger expanse of geography without dependence upon fixed travel schedules of public transportation. At the same time, higher income enables one to acquire, operate, and maintain a vehicle. In 2009, 94.8 percent of individuals with household incomes of \$75,000 or greater were licensed to drive, whereas only 72

percent of people with household incomes less than \$25,000 were licensed to drive. In addition, 95.8 percent of employed people were licensed to drive, compared to 76.3 percent of people unemployed or not in the workforce.

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See Also: Automobile Drivers, Elderly; Driver Licensing; Elderly Driver Safety Issues; Transit Demographics; Transportation and the Disadvantaged.

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Encyclopedia of
TRANSPORTATION



Economic Development

Transportation serves an important function in transforming human society and impacting economic development. This has been studied in several fields, including sociology, geography, planning, economics, and engineering. The diversity of fields has resulted in a complex mixture of theories and empirical studies.

This article addresses the role of transportation in economic development from four perspectives. First, the broad impacts of transportation on economic development are briefly summarized. Second, the impacts are explained by regional economic theories. Third, airports are used as an example for discussing the role of transportation in economic development. Fourth, the complexity of transportation impacts on economic development and the possible reasons for this are explored.

Transportation Impacts

Transportation modes for general public use include bicycles, animals such as horses and donkeys, boats and ferries, personal vehicles, public transportation (such as buses, subways, intercity rail transit, and high-speed trains), airplanes, and others. These transportation tools would not have been used widely without the companion of transportation infrastructure including roads, waterways, highways, railroads, airports, and others.

The advances in transportation tools and improvements in transportation infrastructure have played an important role in decentralizing population and businesses as well as promoting economic growth and development.

The past century saw urban decentralization and low-density sprawl largely due to transportation and communication improvements. Convenient highway networks and personal vehicles allow people to live farther from their workplaces while enjoying low living costs and high quality of life in suburban and rural areas adjacent to metropolitan areas. In addition, the greater availability of air transport reduces travel time between cities, enables increased interactions between them, and integrates otherwise isolated economic regions into a nationwide or worldwide economic region. Intercity rail transit and high-speed trains, which provide safer trip experiences, could further promote the decentralization of population and firms.

Regional Economic Explanations

The way transportation affects economic development has been explained by many theories. Here three regional economic theories are discussed: central place theory, growth pole theory, and neo-classical growth theory.

According to central place theory, transportation infrastructure enables the flow of raw materials, capital, finished goods, consumers, and ideas

between central locations and their hinterlands. Transportation costs are vital for determining locations for both firms and households. For the sake of maximizing profits, business locations are typically chosen based on where costs (including transportation costs) can be minimized and demand is maximized. Meanwhile, preferred locations for households have low land costs and offer easy access to both high wage employment and urban amenities in central areas and natural amenities in outlying areas.

In growth pole theory, the notions of spread and backwash serve to assess how mutually dependent metropolitan areas and their surrounding rural areas are on each other in terms of economic growth and development. This theory mostly looks at highways as a catalyst of change. However, a highway connecting a metropolitan area with its surrounding areas alone represents neither a necessary nor a sufficient influence for economic growth in the two areas; the alternative and equally possible outcome would be economic decline.

According to neoclassical growth theory, transportation infrastructure contributes to the production function. The production function assumes a relationship between inputs and outputs into the production process in an area. Accordingly, investing in transportation infrastructure serves as a type of public capital and flows into the production process. A large proportion of studies in neoclassical growth theory investigate how public capital and economic productivity are connected through the production function. Most claim that economic output increases with an augmentation of transportation infrastructure.

Airports as an Example

The role of transportation in economic development has also been addressed for each individual transportation mode and infrastructure. As an example, airports illustrate the role of transportation in economic development, considering the significant extent to which airports impact human society. Conventionally, it has been presumed that airports significantly promote economic growth and development in both direct and indirect ways. Directly, airports contribute to economic and employment growth because airport operations themselves generate job opportunities, for example, in management and operations functions. Indirectly, positions in supporting services arise: shopping vendors

within the airport and hotels outside of the airport need to be staffed. In addition, the presence of an airport could convince firms to choose a nearby location if they benefit from fast delivery of their products or easy national and international travel. Further, migrants who need convenient access to long-distance travel might find airports a deciding factor for relocation. Long-distance travel afforded by airports is more convenient than surface transportation via highways and railways and reduces limitations of distance on social and economic interactions. Overall, airport development can impact urban agglomeration, business competition, and job creation; the concept of the “aerotropolis” addresses this perspective.

The majority of studies investigating the impact of airports on population and economic growth have been conducted in metropolitan areas and concluded that airport activities enhance economic growth and development. For example, Michael Irwin and John Kasarda studied the causal relations between the presence of airline networks and employment growth in U.S. metropolitan areas. According to them, an airline network causes rather than results from employment growth. Jan Brueckner established that more airline service, such as is reflected by a high number of passenger boardings, significantly boosts urban economic growth. Richard Green found passenger boarding to be a powerful measure to predict population and employment growth in metropolitan areas. The few studies conducted in rural areas have yielded mixed findings. For instance, R. Rasker and colleagues revealed that access to an airport considerably increases economic development in high-amenity rural areas. Yet, A. M. Isserman, E. Feser, and D. E. Warren concluded that the distance to major airports is a relatively insignificant factor for economic development in rural areas.

Mixed Research Findings

However, empirical research does not unanimously suggest that transportation has a positive impact on economic development. The findings are sometimes disparate and contradictory. Some found positive impacts, some found no impacts, and some even found negative impacts. There are at least three possible reasons for this.

First, these studies have been conducted at different points in time, from preconstruction to construction



The Scottsdale, Arizona, municipal airport in 2013. It is a small but economically significant airport 9 miles from the city center. It is also surrounded by a portion of the Scottsdale Airpark, which is one of the largest employment centers in the state of Arizona, housing almost 2,500 companies that together employ approximately 48,000 people.

to postconstruction periods; in each of these phases, impacts of transportation on economic development could be different. During preconstruction, population growth and demand prompt the infrastructure investment. In the time of actual construction, either positive or negative impacts could result as construction represents an inconvenience that might deter people from moving in. Temporary closures of businesses sometimes become necessary, affecting local economic development. However, simultaneously, the increased future value attracts business to move in. The net effect depends on these factors as well as other demographic, socioeconomic, and biogeophysical determinants. During postconstruction, positive impacts are more likely, though they will fade over time.

Second, these studies have been conducted in different types of areas. Transportation impacts on economic development may vary spatially because

growth mechanisms, areal characteristics, and temporal contexts are likely to vary spatially across local areas. For example, in a study examining highway expansion impacts on population change in Wisconsin at the minor civil division level, Guangqing Chi found different impacts across rural, suburban, and urban areas: highway expansion has indirect effects on population change in rural areas, both direct and indirect effects in suburban areas, and no statistically significant effects in urban areas.

Third, these studies are conducted at different geographic scales. For example, immediate neighborhoods tend to view highways as a noise and pollution producer while neighborhoods just a few blocks away focus on the accessibility they provide. A study conducted at the block level is more likely to establish both positive and negative impacts than a study at the county level, in which positive and negative impacts cancel each other out.

Conclusion

Transportation impacts on economic development are a complicated topic. Readers may want to take a comprehensive approach when addressing the role of a particular transportation mode or infrastructure regarding economic development.

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See Also: Benefit–Cost Analysis of Transportation; Economics of Air Travel; Employment Location; Global Economic Centers; Interstate Highway System; Transit Industry, Economics of; Transportation, Economics of.

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Economics of Air Travel

Economists have determined that the prosperity and downturns in the economy, which run in cycles about every nine to 11 years, also affect the airline industry. In general, national and global economies can have great influence on how well the airline industry prospers. The airline industry has had to maneuver around competition with other airlines, shocks to the system from recessions, and thin profit margins.

A good example of how overseas actions can affect the airlines occurred in Iran. In 1979 a revolution erupted to depose the U.S.-supported Shah of Iran, Mohammad Reza Pahlavi, who subsequently fled the country with his family. Not long after, in 1980, Iraq invaded Iran, and oil suppliers in the Middle East almost ceased operations. This created a worldwide panic that soon led to high inflation, higher oil prices, and a slowed economy. The airline industry worldwide suffered a net loss from 1978 to 1981; only when fuel prices returned to the price levels before the panic did they do better. Later on, airlines did well financially.

Since the airline industry appears to follow general U.S. economic success, the mid-1990s saw significant profits for the industry. But even during good periods, profits were not that significant. In 1998, though it was considered a good year, profits were still rather low; net profits, after accounting for interest payments and taxes, rarely achieved even 2 percent overall. But the demand for airline services continued to grow in the same time period.

The industry found its push for deregulation had both benefits and drawbacks.

Deregulation and Customer Service

Before the deregulation or liberalization of the American airline industry, it worked under a number of restraints. During the period from 1934 to 1978, airfares were strictly regulated by the Civil Aeronautics Board (CAB). The CAB did allow airlines to raise prices in order to cover costs but did not let them cut prices to compete with other airlines, or try to make fares more affordable for the middle class. In this way, the CAB actually stifled growth within the airline industry.

Regulation was intended to help maintain consistency in the industry. Although some markets had too much plane traffic and others not enough, at CAB insistence airlines flew direct routes between the same cities, whether the plane was full or not. Fare prices were based on the number of miles the plane flew, so a ticket from San Francisco to New York was about the same cost as a ticket from San Francisco to Hartford, Connecticut.

Unable to cut ticket fares, the airlines resorted to using other methods to attract customers away from the competition. In the 1960s they worked on offering better customer service, such as installing piano lounges and round tables where patrons could sit while waiting for a flight. Or they required their female flight attendants, then called stewardesses, to wear very short, sexy uniforms.

Before 1978 there had been bilateral agreements between pairs of foreign countries in order to control market access, such as points served, traffic rights, and, in many cases, also traffic capacity and travel frequency. This included scheduling of routes and points served so that there would be price controls in those areas. These agreements could also include interairline pooling agreements (or code-sharing) that allowed airlines to share revenue from routes they shared in common. An airline's resulting revenue would be equal to its capacity share, normally 50 percent. This option provided little incentive to compete against other airlines on the international scene, a possibility closed to airlines traveling the United States. Airlines were not allowed to enter into these kinds of agreements for domestic flights because they violated U.S. antitrust laws.

American airlines were eager to have fewer restraints. To gain more control over their industry

and greater access to various markets, the airlines lobbied Congress for deregulation, and they pointed out how Southwest Airlines, which back then flew only within the state of Texas and therefore was not under federal restrictions, had a successful "discount fare" operation. In 1978 President Jimmy Carter signed the Airline Deregulation Act, with the goal of reducing regulation to a bare minimum so that airlines could raise their profits. The Airline Deregulation Act did appear to help the airline economy. It allowed heavily traveled routes, such as between New York and Chicago, to reduce airfares, but at the same time it caused less-traveled routes, such as between Los Angeles and Santa Barbara, to increase fares for passengers. Although there was a fear deregulation would hurt the airlines' safety record, they did not cut safety measures when they cut airfares. Equipment failures and human errors decreased, while air travel, with many now-lower fares, allowed more people than before to experience flying on a jet plane.

Internationally, with the help of bilateral air services agreements, U.S. airlines now had greater access to possibilities previously closed to them. Those included greater opportunity for innovative methods of competitive pricing, elimination of restrictions on frequency and route operating rights, and banishment of unfair fare pricing by U.S. airlines abroad. The act also authorized U.S. cities, specifically, to be designated as international gateway cities and created more competitive air cargo services as well.

In 1992, amid concerns that many international bilateral agreements were actually becoming restrictive, the U.S. and Dutch governments signed the first "open skies" agreement. This assisted the U.S. airline industry further, because the agreement opened the other country to flights to any city in that country. It also provided multiple designations for airlines, no frequency or capacity control unless related tariffs were too high or too low, and enabled these airlines to share codes or other such commercial agreements as would benefit both parties.

This agreement occurred during the Iran–Iraq War, raising fuel prices during a slowing economy. After three years of record losses and bankruptcies, including the demise of Pan American and Eastern Airlines, the U.S. Congress in May 1993 established the National Commission to Ensure a Strong Competitive Airline Industry. The commission

recommended technological and institutional changes to help make it a more efficient industry as well as to improve air traffic control management operations. It also suggested the U.S. government renegotiate its bilateral agreements for even less restriction, for a more open, liberal market environment. The Bill Clinton administration assisted in this effort by endorsing a sole-carrier system, whereby the same airline provided end-to-end services on direct flights or to hub destinations, as well as joint carrier systems that offered connecting flights under code-sharing agreements.

Even with many U.S.-style open sky agreements in effect, the international community still was not totally deregulated economically. For example, in the United States, under so-called fly-America policies, officials traveling on behalf of the U.S. government were required to use only U.S. airlines and U.S. carrier code-shared flights operated by foreign airlines.

More Regulations on the Horizon

By December 1999, U.S. Transportation Secretary Rodney Slater decided to host a conference in Chicago with the theme “Beyond Open Skies.” The government wanted to go beyond open sky bilateral agreements. The European Union (EU) representative, Loyola de Palacio, was surprisingly receptive to the idea. She advised creating a Transatlantic Common Aviation Area, with the common goal of bringing the U.S. concept of open skies in line with the international open market. But no specific agreement was reached during this conference. The United States did permit transatlantic airline alliances, provided they were with European airlines that had signed open sky bilateral agreements with the United States, thereby allowing free entry into relevant markets. The EU was more proscriptive in its approach. It required that partnering airlines in relevant markets give up some runway slots to prospective competitors while also reducing their own frequency of use in any alliance, though they ran the risk of being anticompetitive.

An example of this policy would be changing the time and increasing travel frequencies, in order to make the market for the new airline in the agreement less attractive. This can be specifically illustrated by the U.S. antitrust suit against American Airlines in 1999. The government claimed the airline and its regional subsidiary AMR Eagle had driven three low-fare competitors—SunJet,

Vanguard, and Western Pacific—out of the Dallas–Fort Worth airport through consistent fare reduction and increased frequencies. The Justice Department claimed American Airlines was being “predatory” because the costs of the added flights exceeded their revenues. These cut-rate fares forced Vanguard to cut its frequency down to one flight a day and drove Delta Air out of that market entirely by May 1995. American Airlines defended itself, arguing it was just behaving as a tough competitor should in a very competitive market.

The “open skies” agreements worked for a while, but the problem of European markets still maintaining agreements more to their benefit needed to be worked out. In November 2002 the European Court of Justice (ECJ) issued a series of judgments with important consequences for U.S. airlines. The European Commission had brought eight infringement cases against eight of its member states regarding their bilateral agreements with the United States because of grave concerns on their part. The commission had maintained that it alone could negotiate these bilateral agreements, especially the open skies agreements, because they affected both the flow of traffic between the United States and Europe and created a distorted, contrary competitiveness between European airlines. Another piece of the legal case hinged on whether any EU national company could set up and operate a business in any other EU state.

As the case related to the United States, the ECJ ruled that EU members did have a right to individually negotiate bilateral air services agreements with U.S. airlines. But as legal problems still existed between EU member states concerning bilateral agreements, the United States would have to also modify its bilateral agreements with EU countries. After more legal wrangling and consultation between the European Commission and its member states, the Council of Transport Ministers of the EU adopted three pertinent, all-encompassing measures. First, the commission would be able to negotiate with the United States to fully liberalize (deregulate) air service between the EU and the United States, a move now considered and called “clear skies.” The European Commission would also have the ability to negotiate so-called horizontal agreements, which involved countries outside the European Union that had been mentioned in previous ECJ judgments, but these agreements would

not replace existing bilateral agreements. The third decision agreed upon in June 2003 enabled the Commission to prepare regulations on how air services agreements between EU states and third (outside) countries would be managed and enacted. These judgments have assisted the United States and other countries in their efforts to better serve their customers and business interests.

Labor Concerns

A big financial issue in running an airline well concerns labor. Strong unions and government-owned airlines with union strength have made airline management wary of labor's power, which is not something they can easily control. In the early 1990s, as losses increased, so did pressure to find an avenue to reduce costs. Some European airlines had actually received government funding to help with wage issues, while U.S. airline executives were offering labor share options in the airlines and expecting big wage concessions in order to stay in business. Since that time, labor—a major overhead cost—has continued to be a worrisome issue for airline management.

There are also great variations in labor costs, if one examines several airlines within a region. A review of labor costs in 2002 showed that for larger North American airlines, labor costs have generally ranged from 25 to 31 percent of total expenditures for the airline. For Korean Air, labor expenses were only 11.7 percent of total expenses; British Airways' labor costs amounted to 24.3 percent; Air France was near the top, with labor costs at 33.5 percent of expenses.

What accounts for these percentage rates? Many factors come into play. Prevailing wages in the airline's home country can make a difference, and staffs in different parts of the world can command very different wages. The 2002 review found Air Canada pilots/copilots made \$99,000 a year, compared to SAS pilots at \$200,300 a year. Cabin attendants for U.S. airlines earned \$44,000 a year, compared to Thai Airways' attendants, who earned \$17,800 a year. Flight equipment, type of aircraft flown, overtime payments, and pension and social security funds also add to airline costs and affect wages and company profits.

After the tragic events of September 11, 2001, when planes were crashed into and destroyed the Twin Towers in New York in an act of terrorism, the airline industry and the economy in general

went into a downward tailspin. From that December to December 2004, major airlines lost, on average, 29 percent of their labor force. There was not only a drop in demand but also a threat to low-cost "discount" airlines like Southwest and JetBlue. Since that time, management has found it necessary, at least in the United States, to renegotiate salary levels and conditions of employment periodically, as the economy goes up and down. Passenger behavior has also unwittingly led to cuts in airline support personnel. The popularity of purchasing airline "e-tickets" via the Internet, without travel agency assistance, led to travel agents' market share from 2000 to 2002 decreasing from 68 to 55 percent of bookings; this has continued to decrease in subsequent years.

Profits and Competition

What is the bottom line for the airline industry then? It all depends on the airlines' ability to fill the seats in a plane. If a plane takes off with empty seats, it is considered a missed opportunity; airlines ideally want all seats filled to maximize their earnings. To maximize earnings, they aim for a balance between filling part of the plane with discount fares and the rest with those passengers who have paid the full price for tickets. Airlines also take into consideration peak vacation travel times in their pricing schemes and offer lower cost incentives for flyers to travel on nonpeak days like Tuesdays and Wednesdays, or offer less flexible, nonrefundable tickets purchased far in advance. This may explain why a business executive needing a ticket several months in advance is charged much more than someone surfing Internet Web sites such as Expedia.com or Kayak.com and purchasing a ticket online only a few weeks in advance for several hundred dollars less on the same flight.

Competition, especially coming from deregulation, has not been beneficial for all the industry players involved. During the period from 1978 to 2002, there was fierce competition between different carriers for major routes like New York to London. At the same time, there was very little competition at some airports. Smaller or less traveled airports often suffered; where once several airlines served a small regional airport, now they had only one major airline to go by and at whatever price the airline offered. Of the 11 major airlines that existed in 1978, six have either gone out of business or merged with other

companies: Braniff, Eastern, National, Pan American, TWA, and Western. USAirways is presently planning a merger with American Airlines.

Underserved Markets

Federal transportation and aviation data show the United States has 19,700 airports operating in the country. Of these, 5,170 are open to the general public, but only 503 airports offer commercial service (CS). Of the 503 CS airports, 382 are considered primary airports. This is significant, because primary airports have over 10,000 enplanements a year. Important to primary airports are those considered conveniently located “hub” airports, from which many flights connect to other destinations. There are 29 large hubs in the country, which experience more than 1 percent of the total enplanements annually. At the other usage end are 244 non-hub commercial airports, where fewer than 10,000 passengers pass through a year.

In recent years these nonhub airports have been served more, with the emergence of commuter, shuttle, or regional flights, many of which use smaller, turboprop jets (that have propellers and turbines). A turboprop like Delta’s Embraer EMB-120 craft, which seats 28, is versatile, able to fly from bigger “hub” airports with many connections, like Charlotte, North Carolina, to serve smaller airports with less traffic, like the Tricities Airport in Blountville, Tennessee, or the Roanoke Regional Airport in Roanoke, Virginia. AirTran also flies to smaller markets like Austin, Texas, and Jacksonville, Florida.

Different economic climates, as stated above, affect the airlines. Even in smaller markets, so-called discount airlines, like Southwest, may charge more, as the price of fuel and other fixed costs go up. No airlines are planning to create another Concorde line, a special supersonic, super-fast jet Britain and France sponsored until 2003. Although it could travel from New York to London in mere hours, it used two tons of fuel just taxiing the runway; the horrible crash of one Concorde near Paris in 2000 discouraged many passengers from ever using it again. But the airline industry is adaptable and continues to seek ways serve the public while also making a small profit.

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See Also: Airline Deregulation Act of 1978; Airline Fares; Airline Flight Scheduling; Airline Marketing; Airline Pilots and Crews, Labor Issues of; Airline Service Quality Modeling; Airport Hubs; Airports, Environmental Issues and; Aviation, Ultralight; Helicopters.

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Economics of On-Street Parking

Parking is one of the largest components of the surface transportation system, and certainly one of the largest components of automobile ownership and use. Although many transportation analysts focus on problems caused by moving vehicles, such as congestion and pollution, automobiles also cause problems when they are stationary, because they demand an incredible amount of space for an extremely long time.

One advantage of the automobile is the autonomy it provides; a person with a car, unlike a person with a train or airline ticket, can go wherever she wants whenever she wants. Yet, this freedom from others’ routes and schedules—the freedom to take a car almost anywhere—means there must be room to store cars almost everywhere. Further, most cars are parked most of the time. Though people are seduced by speed and motion when buying vehicles, the average American automobile spends over 95 percent of its life parked. Estimates of the total amount of land in the United States devoted to parking vary but range from 500,000 acres to 11 million acres, or two or three spaces for every vehicle.

Scholars who study the economics of parking focus on the tension created between scarce urban

space and parking's high demands on that space. Much of this tension arises because drivers want parking to be free, and most local governments work to accommodate that desire. In doing so, almost all local governments make two decisions about parking, and both of them—to economists, at least—are mistakes. First, city governments mistakenly price street parking, keeping it free or cheap. Second, they react to the problems caused by that mistaken pricing by requiring developers to provide more parking off-street.

In this way, cities compound a policy that distorts people's driving decisions (offering free or underpriced street parking) by adding a policy that distorts the decision to build. Driving becomes cheaper, but housing becomes more expensive, and the supply of parking steadily rises, making vehicle ownership and use cheaper still. This cascade of bad consequences could be avoided if cities simply charged a market price for curb parking.

Price-Controlled Parking

Curb parking spaces are real estate, and, like all real estate, their value depends on location. A space that provides access to many people, jobs, and amenities—for instance, a parking space in Manhattan—is more valuable than a parking space that provides access to few people, jobs, and amenities. The access offered by a parking space varies both spatially and temporally. A Manhattan space is more valuable at mid-day than at midnight and more valuable at any time than a space in, say, Bozeman, Montana.

Yet, the price of curb parking rarely varies by time and location; price does not reflect value. Most of the time parking on the street—in Manhattan or Bozeman—is just free. Good things rarely happen when governments divorce price from value, and parking is no exception. Underpriced curb space leads to shortages.

At busy times, drivers cannot find curb parking spaces, and complain that the city has “no” parking. In frustration, they circle the nearby blocks, a phenomenon familiar to anyone who has done it or who has had the misfortune of being stuck behind someone doing it. This circling, which is known as “cruising,” has high costs. Travel is beneficial when it helps people get where they are going. Cruising is pure social waste; the people cruising have already arrived and are just adding extra vehicle miles (and imposing extra pollution and delay on everyone

else) in the hope of paying less to park. Perhaps most perniciously, cruising makes neighbors fearful of new development. Existing residents associate new residents or workers with more competition for street parking, and this fear of parking spillover fuels opposition to new building.

Minimum Parking Requirements

One might hope that cities would solve the problem of underpriced curb parking by removing the price controls and charging a price for parking that reflects its value, but one would be disappointed. All too often, cities respond to perceived shortages of curb parking by instituting minimum parking requirements—provisions in the zoning code that require developers to provide off-street parking with everything they build. A typical minimum parking requirement might force a developer to provide one parking space on-site per apartment, or three parking spaces per 1,000 square feet of commercial space.

Minimum parking requirements shift the cost of parking away from drivers and onto developers and therefore hide one of the largest costs of driving inside the cost of housing and other construction. Cities seek to solve a problem of allocation on public streets (a shortage of curb parking) by mandating provision on private land. The results are perverse. Research into minimum parking requirements consistently finds that they are associated with more vehicle ownership, lower levels of housing density, and lower levels of population density.

Housing built on parcels subject to parking requirements has more parking than housing built in deregulated areas, and it also tends to be more expensive. Minimum parking requirements do not, however, appear to solve the problem they were designed to address, which is congestion at the curb. So long as street parking is free, people will park there. Parking requirements have given us a landscape of full curbs and half-empty parking lots.

Market-Priced Curb Parking

The original sin in parking policy is the failure to accurately price the curb, and ending the practice of price-controlled parking could stop the chain of undesirable consequences that flow from it. The keys to this approach are to overcome resistance to pricing and then to price for performance rather than revenue. Pricing is rare, and in most instances,

cities set parking prices based on a desired amount of revenue. The system would work better if cities decided on a target occupancy rate, and then let prices float to achieve that rate.

Suppose a city decided that it wanted one or two spaces on every block to always be vacant, but no more than that. In such a system, the price of parking would be more on Monday than Saturday, more at mid-day than at midnight. Modern meters allow prices to rise and fall across and within days, so pricing of this sort is possible.

Some drivers would pay more than they do now, but they would receive a high-quality service for their money: vehicle trips that end not with cruising and frustration but instead in an easily found empty space near their destination. Less cruising means less pollution and congestion, and with cruising reduced, the need and justification for minimum parking requirements would disappear. Cities could pull the price of driving out of the housing market, and developers could build housing unhampered by costs that more appropriately belong to drivers.

Efforts at market-priced parking are growing but remain rare. Street parking has been free or underpriced for so long, in so many places, that charging for it can seem politically perilous. Yet, cities cannot maintain current practices forever. Governments can hide costs but not make them disappear, and ultimately, cities may need to decide that drivers, not developers, should pay for the costs of storing vehicles.

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See Also: Parking Demand; Parking Lots; Parking Planning and Management; Parking Regulation and Enforcement; Parking Revenue and Collection.

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Elderly and Disabled Travelers

It is widely acknowledged that elderly and disabled travelers face a number of difficulties in accessing and using both public and private transport systems. Much effort has been focused on making modifications to physical infrastructure and vehicles and making reasonable adjustments to services in order to enhance their accessibility, and this has served an important role. In addition to this, however, the emergence of new technological opportunities is offering new potential solutions to transport inaccessibility but also new potential problems of inaccessible technologies. Making best use of the technological possibilities for enhancing transport accessibility is a challenge, but one that, if it is met, offers enormous scope to improve mobility, health, and well-being.

The World Health Organization (WHO) estimates that there are over 1 billion disabled people worldwide and highlights that this figure is on the increase and predicted to continue to grow in the coming years. The upward trend in disability stems from the trend toward an ever-aging population and the higher risk of disability among older age groups and the increasing prevalence of chronic health conditions, such as diabetes, cardiovascular disease, cancer, and mental health disorders.

In most parts of the world the proportion of older people within the population is increasing. As the population ages, the likelihood of impairment increases. How one defines "disability" can become contentious, depending upon the extent to which it is viewed as a medical issue or a social issue; that is, whether the source of disability is viewed as emanating from the individual's medical condition or from society's failure to organize itself in a way that accommodates the diversity of the population. Nevertheless, there is widespread acknowledgment that

disabled people face a range of barriers to accessing everyday goods and services, such as transport, housing, and education, and that these barriers result in diminished life opportunities for disabled people. For example, disabled people tend to have poorer health outcomes, lower educational attainment, lower employment rates, and lower incomes than nondisabled people. Consequently, there is a widespread acceptance that efforts should be made to reduce or remove these barriers, and many countries have passed legislation to enforce and embed such efforts. At the global level, the United Nations has put in place the Convention on the Rights of Persons with Disabilities (2008).

In terms of barriers to travel and transport, the principal response at first was to provide alternative transport services designed especially for disabled people, but as these specialized services became increasingly difficult to scale up and as the broader agenda turned more toward the inclusion of disabled people within the mainstream of society, attention turned to developing a more inclusive approach to travel, with the focus on tackling the specific barriers to access within mainstream transport services.

Five types of barriers to access can be distinguished: physical design (of the built environment and of transport infrastructure and vehicles), transport service availability/proximity, financial affordability, information and awareness, and training.

New Technologies

The following broadly adopts the categorization set out in the Organisation for Economic Co-Operation and Development's 2003 report, "New Transport Technology for Older People," which remains a very relevant document even now. This makes a three-way division of technological applications, as they are applied to a vehicle, a person or to the physical infrastructure.

In-vehicle systems. In-vehicle systems for private cars have generally been developed by motor manufacturers based on commercial incentives to increase driver safety, confidence and comfort, with an awareness of the growing size of the older driver market.

Adaptive speed control. Linked with Intelligent Sped Adaptation, this technology serves to help



Blind visitors to Olomouc, Czech Republic, in 2011 use their hands to learn the layout of the city center from an outdoor model that serves as a three-dimensional map for the visually impaired. Higher tech options in development include Blind Square, a smartphone app that links with the app FourSquare.

drivers maintain safe following distances even as the traffic ahead changes speed. Maintaining a safe following distance reduces the chance of a rear-end collision, and this technology serves to compensate for reduced reaction times on the part of the driver. Three levels of intervention are possible, ranging from the provision of an alert to the driver, to regulation of the throttle, to automatic application of the brakes. Tests have demonstrated the success of these technologies, though there are some problems of user acceptance associated with drivers' unwillingness to delegate active driving roles to the in-car technology.

Night vision displays. Employing a specialised camera to project an intensified image of the view in front onto a Heads Up Display (HUD), these systems serve to augment diminished nocturnal acuity and/or to enhance the range of sight. The HUDs

can also be used to provide additional overlaid information, or even augmented reality views to aid the driver. In this way, they can compensate for the deterioration in night vision often experienced with aging and safely reduce the older driver's tendency to self-regulate their driving behavior by minimizing night-driving.

Navigation systems. Now fairly commonplace, navigation systems combine satellite tracking and digital mapping to provide navigational assistance to the driver. Perhaps of particular help to the older driver whose ability to recall routes or to orientate in unfamiliar surroundings may be diminished, they can also be configured to direct them to less-busy roads, to avoid difficult junctions, and to provide advanced warning of lane-changes. However, there are also a number of concerns raised regarding the human-machine interface and whether the devices are designed appropriately for the older driver, regarding the extent to which a navigational aid becomes a driver distraction, and regarding the accuracy of the mapping information used.

Gap-estimation aids. These technologies measure the distance and speed of oncoming traffic at intersections and then provide a visual and/or auditory alert to the driver when it is safe to turn across the oncoming traffic. Accident statistics have shown older drivers to be over-represented in intersection crashes, probably linked with the declines in vision, cognition and reaction-time associated with aging, and it is thought that these technologies could serve to mitigate these problems.

Workload management systems. With the multiplicity of demands on driver attention, workload management systems seek to integrate and regulate in-vehicle systems and the signals, alerts and information they send out. The key to their function is said to be the inference of cognitive load based on vehicle data, enabling the prioritization of the different in-vehicle systems such that undue demands are not placed on the driver. Examples could include an automatic moderation of the volume of the in-car audio system when the navigation system detects a complex intersection, or the diversion of an incoming phone call to voicemail when heavy rain is indicated by the windscreen wipers being on full.

Personal Technologies

Personal technologies are being used to develop solutions for different disability groups. A great deal of effort has focused on technologies to assist visually impaired people. To a lesser extent, solutions have also targeted wheelchair users and others with reduced mobility and people with hearing or other communications impairments.

Smartcards. Smartcards provide for easier and more convenient transport-related payments, for example, for parking, for public transport, for paratransit and/or for taxis. They remove the need to sort through coins or bank notes, something which can be difficult for those with impaired dexterity or sight/touch. Contactless smartcards, based on RFID technology, can even be used without requiring users to remove the card from their pocket or wallet. Furthermore, smartcards can also be used to store customized accessibility-related information relating to the user, which could be shared with, for example, on-bus systems as a means of communicating with the driver or of reconfiguring a car's in-vehicle system for the particular requirements of that elderly or disabled driver.

Personal navigation aids. There are two main categories of personal navigation aids: those that provide passenger guidance and those that offer tailored accessibility-related information.

Passenger guidance for visually impaired people seeks to make use of satellite navigation technologies, in conjunction with screen magnification and speech synthesis technologies, in order to provide route navigation and wayfinding information to people with a visual impairment. Passenger guidance based on GPS and mapping technologies, often referred to as personal positioning systems (PPS), has been implemented in two principal ways. First, for much of the past two decades, implementation has been via specialist devices, designed for visually impaired people with the dedicated purpose of providing passenger guidance; the Trekker Breeze is the most recent example of this. While the portability of these devices has improved over time and their price has reduced, their purchase price is still in the range of 150 to 400 euros. Second, implementation has more recently been via applications (apps) designed for Internet-enabled mobile phones and smartphones, because the required technologies

are often already integral to the mobile device. The following are three examples:

- *Navigon*. This uses the mobile device's GPS capability and links with digital mapping to provide a fully functioning mobile navigation system, enabling text-to-speech voice guidance, turn-by-turn pedestrian directions, a "take me home" function, and links to the user's contact list to provide directions to a selected contact.
- *Blind Square*. This uses the IOS device's GPS capability to determine the user's location and then links with FourSquare and Open Street Map to look up and provide, in its synthetic voice, information about nearest street intersections, nearby shops, restaurants and other facilities, and distance traveled.
- *SeeingAssistant-Move*. Launched in 2013, this provides for route planning and route recording, advanced neighborhood scanning with world directions, location search, "where-am-I" functionality, input of sharing points, and use of voice commands.

Furthermore, the Royal National Institute of Blind People (RNIB) have been conducting groundbreaking work in the areas of augmented reality, electronic recognition and artificial vision. They see these as forming part of a "blended technological" solution, whereby technologies serve to complement techniques already being used, such as the long white cane and the guide dog.

Tailored accessibility-related information and communication apps for wheelchair users and other people with reduced mobility draw on digital maps and crowd-sourced data, often provided in real time. Examples of some of these currently on the market are as follows:

- *Jaccede*. This app was launched in 2012 and enables users to search for places that are accessible to those with a disability. Information, such as whether the entrance is step-free and accessibility of toilets, is displayed alongside photos, user comments, and other relevant information. Users can contribute by adding accessible places anywhere in the world or by editing

existing listings. The app was a winner of a Vodafone Smart Accessibility 2012 award, in the mobility category.

- *Assistmi*. This app can be used by disabled people to alert participating sites, such as shopping centers, railway stations and airports, to know when they are on their way and when they have arrived, while conveying all their access needs so they can be met by staff and properly accommodated. In addition, the Parking Space Finder function can help locate nearby Blue Badge (disabled parking) spaces and indicate how far away the space is, any special parking restrictions the space may have, and what kind of parking it offers.
- *GoGenie*. This app aims to help disabled and deaf people find access information online for any location, such as a shop, cinema, cultural event or town centre, based on the recommendations and comments of others. Specific features include access information, contact, maps, facilities to add reviews, photos and videos, and a "report-it" feature enabling people to complain directly to inaccessible venues and organizations.
- *Ldn Access*. This app is designed to be used as a source of access-related information for places to eat, hotels, entertainment, attractions, etc., throughout London. It is targeted slightly more broadly at disabled people (either physically or nonphysically or both), older people, families with young children, and visitors to London, and provides information on wheelchair access, disabled toilets, induction loops, baby changing facilities, customer parking, etc.

Physical Infrastructure

New technologies have also been embedded into the physical infrastructure of the built environment. Triggered Information, via the use of Beacons, has been the subject of research and development, and the RNIB has recently launched its update to their REACT system of talking beacons for visually impaired people. A further idea is that of "electronic leadlines," whereby RFID tags are fitted to the visually impaired person or to their long white cane, which then interact with tags in the environment.

The aim is to enable the visually impaired person to be prompted and guided in unknown environments, but it could also serve to improve cognitive awareness of one's surroundings. The Austrian "ways4all" project has undertaken ground-breaking work in this area, establishing several demonstration sites in Vienna. However, it is not possible to embed RFID tags everywhere, so the question returns to the issue of how to use what is already there to best effect.

Limitations

There are several scientifically exciting technological developments taking place, but a number of difficulties remain. Acceptance of new technology, particularly among older age groups and lower income groups seems to continue to be a problem. Likewise, technology abandonment has been shown to be commonplace, particularly where that technology has been designed especially for the elderly and disabled market. This would seem to be a result of several factors, including awareness of the technologies, cost to the individual, accessibility/user-friendliness of the technology itself, and a lack of availability of training specific to the technologies.

Add to this the problem of battery life for the devices, and it would appear that new technologies might be best seen as providing a complement—albeit a powerful one—to a travel environment that is itself inclusively designed.

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See Also: Automobile Drivers, Disabled; Automobile Drivers, Elderly; Disabled Driving and Vehicle Modifications; Emerging Technologies; Handicapped Access; Travel Patterns of the Elderly.

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Elderly Driver Safety Issues

Elderly drivers have higher accident rates than other age groups and are considerably more vulnerable to injury. Driving at an advanced age carries added risks due to limitations to perceptual, physical, and cognitive functioning. Specific medical conditions and the use of some medications can also increase the risk of accidents. The increase in the number of older drivers poses ethical questions at the level of public policy, as the objective of ensuring road safety must be balanced with the need to provide older people with the means to have independent mobility, which is linked to life satisfaction in this age group. Regulations regarding driving license renewal and assessment of driving ability are in effect in most countries. However, policies have also been designed to promote the inclusion of drivers in a safe road environment, through education and training. Developments in vehicle and road design may also contribute to ensure the safety of older drivers.

As a result of the increase in life expectancy and decline in birth rates, a large proportion of the population in developed countries is of an advanced age. General improvements in health and income also mean that more elderly people are now driving, both in absolute numbers and as a proportion of all drivers, while sociocultural changes have led to an increase to the proportion of older women drivers. In most countries the accident rate of elderly drivers is relatively high but lower than the rate of the youngest drivers (aged 16–24). In addition, because older people drive less than younger drivers, they are responsible for a smaller number of accidents. Nevertheless, elderly drivers are a special group of concern in terms of road safety because they are more vulnerable to injuries. In fact, the probability of long-term disability and mortality tends to be much higher for older drivers involved in car

accidents than for younger drivers, mainly because of their frailty. Safety issues are especially relevant for the older elderly (over age 75).

The cause of accidents involving elderly drivers tends to be specific to this age group. A large proportion of accidents can be explained by errors and lapses, such as failure to stop at red lights and stop signs, to give or yield right-of-way, and to respect other road signs. Other common causes are vehicle maneuvers in dangerous or confusing road environments such as sinuous road alignments, multi-lane roads, and complex intersections.

On the other hand, statistics and surveys show that older drivers adapt their driving patterns to compensate for some of the limitations they face. This includes driving slower, allowing wider gaps for merging with traffic, and avoiding driving in complex road environments, at night, under poor meteorological conditions, and on roads in poor state of repair or with wet and icy surfaces. Factors causing accidents in other age groups, such as excessive speed and driving under the influence of alcohol and drugs, are relatively less important in the group of older adults.

Functioning

There are several factors limiting the driving ability of elderly people. The aging process reduces the individuals' perceptual functioning. The most researched aspect regards losses in visual abilities. Older adults face limitations in terms of contrast sensitivity, night vision, ability to perceive detail, reduced visual field, depth and motion perception, and recovery time from exposure to bright lights. These factors influence the drivers' perception of road signs and of other elements of the road environment and limit their awareness and assessment of speed and distance from other vehicles, especially when compounded with limitations in other sensory processes such as hearing. Limitations in visual abilities also intensify the accident risk caused by driving at night or in foggy or rainy weather.

Physical functioning is also limited in older adults. This includes aspects such as strength, flexibility, and coordination. The ability to move parts of the body is crucial to driving. Restrictions to the motion of the neck increase the difficulties in seeing road signs and in assessing the different elements of the road environment. Joint stiffness may also limit the speed and coordination of movement. This may

reduce control of the vehicle, such as the ability to use the steering wheel to veer the vehicle and to use feet to control the accelerator and brake pedals. All these aspects can influence elderly drivers' reaction times to adapt to unexpected events on the road, a factor that is crucial in many road accidents.

The limitations to perceptual and physical functioning become more relevant for driving safety when in conjunction with limitations to cognitive functioning. Older drivers are more likely to suffer impairments in the capacity for concentration, speed of information recognition and processing, and short-term memory. Losses of attention and problems in sorting different types of information can also cause problems due to the distraction caused by the presence of disparate elements competing for the driver's attention on the road, such as road signs and other vehicles, while controlling the vehicle. This increases the probability of misjudgments leading to making wrong decisions and prolongs reaction time.

Elderly drivers are also at an increased risk due to the effects of the progression of specific medical conditions. Dementia and other neurological conditions are related to the probability of making errors while driving, as they contribute to the loss of attentiveness and failures to obey traffic rules and make the right decisions. Conditions impairing visual perception, such as cataracts and glaucoma, also have a marked effect on accident risk, as they contribute to the loss of visual acuity and the reduction of the visual field. Conditions impairing flexibility, such as arthritis, are also relevant because they affect the ability of the driver to control the vehicle. More research is needed on the effects of other conditions that are relatively more common in old age, such as metabolic, cardiovascular, and cerebrovascular diseases. More knowledge is also needed about the way that some of the medications used to treat some medical conditions prevalent in old age interfere with driving, especially the interacted effect of several medications.

Policy

Whether public policies should or should not promote driving in old age is an ethical question. The increase in the number of elderly drivers increases the risk of accidents for all road users, which has substantial costs for society as a whole. The problem is bound to become more serious in the future as

the number of active older elderly tends to increase. On the other hand, driving cessation has important psychosociological aspects. Driving allows for independent mobility, which is a critical component of the physical, mental, and social well-being in this age group. In dispersed suburban and rural communities, the car is also the major and sometimes only mode of transportation. The ability to drive also contributes to freedom and autonomy to a great degree. Elderly people who cease to drive may therefore feel they are losing independence and suffer role loss. Public authorities should thus consider the balance between the promotion of driving in old age and the application of policies providing alternatives for the lost mobility when individuals cease to drive, including the supply of public transportation, decentralization of facilities, and improved communications.

Regulations

Most countries have regulations regarding the driver's license renewal of older individuals. The issue is often subject to public discussion as there is no consensus regarding the specific role of age in accident risk. As such, regulations are not based exclusively on the driver's age and involve a mandatory assessment of their driving ability. However, the frequency of this assessment usually increases with the age of the driver. The evaluation process usually includes tests of visual acuity and other relevant abilities and may also include on-road driving assessments.

The evaluation of the ability to drive can also be made at the level of general clinical screening, usually in the case when a specific medical condition is identified. Guidelines for this assessment are in many countries provided by medical associations and transportation authorities. The *Physician's Guide to Assessing and Counseling the Older Driver*, published by the American Medical Association and the National Highway Traffic Safety Administration, is one example.

The application of strict regulations for renewal of driver's licenses for elderly people is often controversial due to the psychological factors involved in cases where the individual fails to pass the test; this may trigger depression and accelerate physical decline. Critics of this type of regulation point to the fact that in many cases there is opportunity for attempting a correction of the impairments in perceptual and physical impairments that limit

driving, while acknowledging that psychological support is also needed when the only option for the regulator is to revoke a driver's license.

Education and Design

Safety for driving older adults can be enhanced by education and training programs organized by public authorities and other organizations. The content of these programs usually includes an update on traffic laws, vehicle characteristics, and road environment, as these elements may have changed since the time when the individual learned how to drive. The programs may also include training regarding the specific limitations on driving caused by old age and tips to help drivers to develop strategies for identifying hazardous road conditions and driving behaviors. Training programs can also help individuals to prepare for driver license renewal tests and cover practical issues regarding the necessary procedures.

The safety of older drivers can also be enhanced by improvements in both vehicles and road designs. Vehicle manufacturers can add equipment to address specific old-age-related limitations, such as adjustable steering and brake and accelerator pedals, flexible and comfortable seating and safety belts, and larger windows and rearview mirrors. Devices such as geographic information systems and night vision enhancement can also provide useful information to help the driver to safely navigate the roads and steer the vehicle. The design of roads should also take into consideration the needs of elderly drivers, especially in the neighborhoods where the majority of the population is elderly. Important factors include lighting at intersections and the size and legibility of road signs and markings. Finally, the application of some traffic rules for all drivers, such as the mandatory use of daytime headlights, may also contribute to the safety of elderly drivers.

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See Also: Automobile Accidents and Prevention; Automobile Drivers, Elderly; Elderly and Disabled Travelers; Traffic Safety; Travel Patterns of the Elderly.

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Electric Diesel Locomotive

Electro-diesel or dual-mode locomotives are locomotives with the ability to draw power either from their diesel engine or from an electricity supply (typically provided, as with all-electric locomotives, by overhead lines or a third rail). Diesel engines work like those of conventional diesel trains, by burning diesel fuel to power a generator that produces electricity in order to run electric motors in the wheels. Though they are not in widespread use, they have the obvious advantage of being able to reserve diesel consumption for those times when no electricity supply is available, reducing overall emissions. They also permit movement through areas where diesel engines are banned.

In addition to electro-diesel locomotives, which are railway cars that serve no function except to provide locomotive power for the train as a whole and have no payload capacity, there are electro-diesel multiple units, which are self-propelled railway cars that may either travel on their own or link up to other cars and be controlled by a locomotive. (This is not to be confused with the similar railway term, *multi-unit control*, referring to the process of controlling multiple locomotives.) While multiple units are not commonly used in long-distance railways in the United States, they are common in light rail and commuter trains, some of which are electro-diesel.

Low-speed trains sometimes use a primarily electric design, coupling an electric locomotive with an auxiliary diesel prime mover. This type of design is mainly used for rail lines that have brief gaps where electrical power is unavailable. At the other end of the spectrum, some primarily diesel trains are equipped with auxiliary electric motors for use where diesel engine use is banned. For instance, in the United States the confined spaces and heavy train traffic of

Penn Station and Grand Central Terminal have led local authorities to ban diesel emissions in those stations. Entering locomotives switch over to electric, drawing power from the third rail, before retracting the third rail "shoe" (the connection that draws power) when reentering diesel-friendly zones. In both these cases, the train is primarily diesel or electric, with the other mode used to provide power in a limited set of circumstances when the main power source is unavailable. Historically, most electro-diesel locomotives have been one of these two types. Full dual-mode electro-diesels have become easier to design, build, and operate as computers have improved transportation technology, and are often equipped with onboard computers that automatically adjust between modes as circumstances dictate. Full dual-mode electro-diesels are better suited to long-distance routes and have been advocated as a transportation solution for 21st-century America.

One of the earliest electro-diesel locomotives was the General Electric three-power boxcab, developed in the 1920s and called an "oil-electric" because of the unpopularity of German terms such as *diesel* in the post-World War I years. The boxcabs could switch between diesel and electric as described above but could also run on direct current electricity provided by batteries. Dozens of the locomotives were made, but production fell off when the Great Depression began. The three-power boxcab is similar in some respects to the modern hybrid locomotive.

Hybrid locomotives are an improvement on older electro-diesel designs, using ultracapacitors and modern fuel cells, and are reminiscent of hybrid motor vehicles. Like other electro-diesel locomotives, they can run on either diesel fuel or electricity. Like full dual-mode locomotives, they are designed not with an auxiliary motive source to make up for a few short gaps in the route where the main motive source cannot be used but with the intention of switching back and forth frequently. Unlike locomotives drawing power from a third rail or overhead lines, however, hybrid locomotives use onboard batteries and have the prominent advantage of being usable without waiting for infrastructure improvements. The first "hybrid" locomotives combined steam and diesel power, but today's hybrid locomotives use an onboard rechargeable energy storage system (RESS). Locomotives are relatively easy to convert to hybrid design, especially compared to automobiles.

The batteries are charged with surplus energy from the diesel engine and sometimes from regenerative braking, an energy recovery system that assists with braking the train by converting the kinetic energy of the train's forward motion into stored electricity instead of the waste heat generated by the friction of conventional braking. (Regenerative braking only works well until the train has slowed down, at which point the conventional braking system brings the train to a full halt.) Regenerative braking has been used on locomotives since the 1930s. In fact, in some Scandinavian mining communities, trains bearing ore generated more energy going downhill (when the brakes were needed for much of the trip in order to slow the heavy train) than they used, and that excess electricity was pumped into the local power grid, providing electricity for the local residents. Of particular interest today is the fact that electricity generation through regenerative braking is a carbon-neutral form of electricity generation, which helps offset the environmental impact of operating a diesel engine. Regenerative braking has also long been used in the race cars used in motor sports.

Hybrid electro-diesels typically draw their power from both a diesel engine and batteries, but some may also have the ability to draw electricity from a third rail or overhead lines, depending on the route they serve. The Canadian company Railpower began operating experimental electro-diesel hybrids in the United States in 2004, which have since been adopted by a number of railways. Railpower's hybrid design, called the Green Goat, has 90 percent lower emissions than full-diesel trains of similar payload. The Green Goat uses a six-cylinder 300-horsepower inline engine (manufactured by Caterpillar) and a bank of batteries providing an additional 1,700 horsepower. They have a top speed of 60 miles per hour. Over 50 Green Goats have been produced and sold to Canadian and U.S. companies, deployed by the BNSF Railway, the Canadian Pacific Railway, the Kansas City Southern Railway, the Modoc Rail Academy, Railserve, the Union Pacific Railroad, and the U.S. Army. BNSF has experimented with converting its Green Goat from a diesel engine to one using hydrogen fuel cells, a design similar to one used in Japan in smaller locomotives.

General Electric's GE Evolution Series of low-emissions locomotives includes a hybrid electro-diesel using sodium-electric batteries and regenerative braking. A hybrid electro-diesel using biodiesel

has also been added to the streetcar line of the city of Savannah, Georgia, and has been in operation since 2009 as part of the city's attempts to reduce environmental impacts and air pollution.

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See Also: Diesel Engines; Diesel Fuel Vehicles; Hybrid Automobiles/Hybrid Electric Vehicles; Trains.

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Electric Vehicle Recharging Stations

Electric vehicles (EVs) include plug-in hybrid and battery electric hybrid (BEVs) cars that use a battery to power a vehicle's motor. They include cars, buses, scooters, motorcycles, and small short-range vehicles. In the case of plug-in hybrids, drivers can use either traditional fuel for an internal combustion engine or plug the car into the electric grid.

EVs and plug-in hybrids, when powered by the battery, offer a number of benefits to the owner and the environment. EVs have no tailpipe emissions, thereby reducing the amount of greenhouse-gas emissions attributed to driving. Because the vehicles use electricity instead of petroleum-based fuel, they cost less to operate than a traditional combustion-engine-powered vehicle and have lower maintenance expenses.

Though EVs do have a carbon footprint associated with electricity production, they have less impact than traditional vehicles, especially when the grid uses wind, solar, or water to generate electricity. Engines in EVs are more efficient, converting approximately 60 percent of their electrical energy

to power, versus conventional vehicles which convert just around 20 percent of the stored energy in gasoline to power. Most models operate quietly and have competitive acceleration.

Electric Vehicle Prevalence

Because EVs have less negative impact on the environment and do not depend as much on fossil fuels as traditional vehicles, many countries have set aggressive goals for increasing the percentage of EVs on the road. Fifteen countries from around the world have joined the Electric Vehicle Initiative (EVI) to encourage the use of EVs in member countries, eight of which are among the 10 largest vehicle markets worldwide.

EVI countries claimed 180,000 electric vehicles, excluding motorcycles, buses, and heavy duty vehicles, or 0.02 percent of total passenger cars. The Electric Drive Transportation Association reports that fewer than 100,000 electric cars have been sold in the United States since 2011, which represents

just 0.13 percent of total new vehicle sales. In 2012, according to *USA Today*, automakers sold 53,172 plug-in electric vehicles and 434,498 hybrid vehicles, a total market share of 3.4 percent.

The Chinese Association of Automobile Manufacturers Association reported 12,791 sales of hybrid and electric vehicles in China, but after eliminating vehicles, such as golf cars, that are not roadworthy, the number shrinks to approximately 3,000 vehicles. In the smaller Norway market, the Nissan Leaf is the fifth-best seller among car models, but in the United States, where Nissan had planned to sell 20,000 vehicles, only 9,819 have been sold and fewer than 50,000 of the model have been purchased worldwide.

Despite EVs being slow to catch on with consumers, a market study by Pike Research estimates that by 2020, annual global sales of electric or plug-in hybrid cars will reach 3.8 million. Currently, the highest rates of EV ownership are in the United Kingdom, Germany, Japan, China, and the United States, and the use of EVs in government and corporate fleet vehicles is increasing. Some countries, such as the United States and the United Kingdom, as well as individual states, provide tax incentives to purchasers of EVs to encourage usage.

Barriers to Adoption

Consumers may eschew EVs for many reasons. Plug-ins tend to demand a premium price because of the expense of the battery, a part that usually needs to be replaced at least once. The Chevy Volt, for example, retails for over \$40,000 in the United States, and the Nissan Leaf ranges from \$28,000 to \$34,000. High-end Tesla EVs can cost between \$62,000 to \$82,000. In the United Kingdom, EVs range from \$31,000 (£20,000) to \$46,500 (£30,000).

Some consumers are reluctant to purchase EVs because of their relatively short driving range, 100 to 200 miles, between charges. According to the EVI's "Global EV Outlook" report, 75 percent of Americans surveyed were wary of the range restrictions, even though studies indicate that the average car trip in the United States is just over 9 miles, and daily travel is just over 28 miles, on average. Gasoline-powered cars can go up to 300 miles before needing to refuel, and drivers enjoy the confidence of knowing that a gasoline station will be nearby.

EV drivers have fewer options for recharging their vehicles. In the United States, there are 5,800



A Chevrolet Volt recharging in Fremont, California, in 2012. As of 2013, there were only about 5,800 public recharging stations in the United States, while there were over 167,000 gasoline stations. Batteries can be charged up to 80 percent in 30 minutes.

public recharging stations, compared to more than 167,000 gasoline stations. The United Kingdom offers approximately 200, compared to more than 9,000 gasoline stations, while Japan has nearly 2,000, compared to 38,000 gasoline stations. Many EV owners who have off-road parking have private recharging stations in their garages or driveway.

To fully recharge an EV's battery pack can take as long as eight hours, though quick charges that fill the battery to 80 percent capacity can be done in half an hour. In most countries, smart phone applications or Web sites provide searchable databases with maps to help consumers locate the nearest recharging stations. For residents of apartment or homes without off-street parking, EVs may be out of reach because it is not possible to install a recharging station at home.

Electric Vehicle Supply Equipment

Recharging stations, also known as electric vehicle supply equipment (EVSE), are categorized into Level 1, Level 2, and DC Fast Charging types. Level 1 EVSE uses 120-volt AC plugs and adds 2 to 5 miles of range for each hour the vehicle is charged. Level 2 equipment utilizes 240-volt electrical service and adds approximately 10 to 20 miles of range for each hour charged. DC Fast Charging EVSE, with 480 volts of AC input, provides 60 to 80 miles of range for each 20 minutes charged.

The company Better Place, which operates in Denmark and Israel, promotes replaceable or switchable batteries, so that drivers can go to a battery switch station and, in a matter of minutes, exchange depleted batteries for ones with a full charge. One challenge for users and manufacturers of EVSE can be opposing standards for plugs and receptacles. SAE International provides the Combined Charging Systems protocol, adopted by German and U.S. automobile companies, while CHAdeMO offers a competing set, adopted by Japanese car manufacturers. While all North American cars and chargers follow SAE's protocol, the incompatible standards can be particularly vexing to European drivers, who drive more frequently across national borders.

Public recharging stations can be paid for by companies wanting to contribute to environmental initiatives in the community. These might be available for employee use to encourage employees to drive environmentally responsible cars, or they might be available to customers as an incentive

for frequenting the business. In the United States, for example, Walgreens is the largest retail host of EVSE, and as of 2012, the company planned to install 800 at their locations nationwide. Some companies, such as public garages, might provide recharging station access for a fee, allowing it to become a revenue generator for the business.

Initial costs for EVSE include the station itself, as well as installation by a professional electrician. Long-term costs include maintenance and the electricity attributed to the charging. In peak times, this can be a concern. Many national and state governments who want to promote the acceptance of EVs provide grants or subsidies for EVSE installation. In Illinois, homeowners, businesses, and community colleges can receive grants for half of the EVSE installation expenses as part of the 2900 Illinois Jobs Now! Act, which earmarked \$10 million for EV infrastructure.

Nationwide, the American Recovery and Reinvestment Act (ARRA) provided a federal stimulus grant of \$114.8 million, matched by private donations for a total of \$230 million, administered by the U.S. Department of Energy for the EV Project, managed by the firm ECOTotality. The EV Project is active in nine states and the District of Columbia with a goal to promote an EV infrastructure. Fifteen thousand charging stations were available to commercial and residential applicants. As of March 2013, all available units had been distributed, exceeding anticipated public demand.

Public charging stations use Level 2 or DC fast charging. If public charging stations are located conveniently with some density, consumers will likely feel more comfortable with the driving range of EVs. With more EVs on the road, emissions are decreased. Additionally, public stations can allow drivers of plug-in EVs to recharge and use the battery rather than the gasoline engine, further reducing harmful emissions into the environment.

Some areas, such as Sonoma County in California, have extensive guidelines and a permitting process, including a site plan for placement of an initial EVSE infrastructure. Other areas install recharging stations on a more ad hoc basis. Sonoma County outlines three considerations for potential hosts of public recharging stations, which are relevant in all areas.

First, the site location should be conveniently located and near heavy-traffic corridors, and the

site should have adequate electric service, be out of flood zones, and away from water. Second, the host should review the user base of the potential EVSE, considering the peak hours, the walking distances to attractions and retail establishments, and perceptions of safety. The third consideration is the parking location. In this area, the host should consider the placement of the chargers, the signage needs, the available light, placement of cables, the demand on the electric system of the building or structure, and accessibility for mobility impaired users.

For those who install private or public EVSE, as well as for communities as a whole, another concern of EVs is the strain on the electrical power grid. Research for Mueller, Texas, a neighborhood with the highest concentration of Chevy Volts in the United States, found that most residents plug in their cars when they get home from work at the end of the day, the same time they turn on the television and computer, adjust climate controls, and use kitchen appliances. Such high concurrent usage in American cities, where the grid is relatively well-developed, could still potentially cause blown circuits, but in countries such as France, where the electric grid has little flexibility at peak periods, representatives of the French power company, RTE, fear that heavy use of chargers at peak hours could cause power surges and possibly disruptions in service.

Companies are researching smart charging mechanisms to incorporate into EVSE so that when plugged in, the EVSE will detect the best time to charge based on the grid demands. Other researchers are testing how electric vehicles might store excess capacity in the grid during off-peak usage in their batteries and sell it back to the power companies.

EVSE Vendors

A number of manufacturers produce recharging stations. The company 350Green manages site selection, engineering, construction, and marketing of recharging stations, and works with municipal and corporate partners, including Walgreens. PEP Stations provides recharging stations for public EVSE hosts that can accept major credit cards.

In addition to managing the EV Project, ECOTALITY produces Blink recharging stations, notable for their sleek style and flat screens to process transactions and display advertisements. A long-time

partner with automobile manufacturers, Bosch also supplies a line of residential and commercial recharging stations in the United States, Canada, Europe, and Asia. A division of Control Module Inc., EVSE LLC offers portable recharging stations for valet parking and service bays.

Future Concerns

For electric vehicles to gain in popularity, a number of agents must work in concert. Governments must provide incentives and assist in the development of an infrastructure. Electric companies must find ways to work with EV users to diminish strain on the grid. Car manufacturers must produce competitive and interesting models of EVs. Consumers and corporate purchasing agents must be willing to purchase electric vehicles.

Governments throughout the world are working with manufacturers to install recharging stations and develop a strong infrastructure for electric vehicles. However, it seems the other elements are not yet coalescing into momentum to substantially increase the number of EVs on the road. Without consumer demand, manufacturers are focusing production on high-mileage traditional vehicles or plug-in hybrids.

Nissan Motor Company, one of the biggest supporters of EVs among car manufactures, announced that it was shifting its strategic focus to plug-in hybrids, and Toyota Motors is developing hydrogen-powered fuel-cell technology instead of manufacturing battery-powered electric cars. The current push for expanding the infrastructure of recharging stations could mark the beginning of the era of electric vehicles, or it may eventually stand as a monument to another failed effort to wean drivers off of fossil fuels.

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See Also: Alternative Automotive Fuels; Electric Vehicles; Hybrid Automobiles/Hybrid Electric Vehicles; Light Electric Vehicles; Sustainable Transportation.

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Electric Vehicles

When President Barack Obama, in his 2011 State of the Union address, set a goal of putting 1 million all-electric vehicles on America's roadways by 2015 (the first country that would achieve that milestone), comparisons were inevitably drawn to President John F. Kennedy's bold clarion call nearly a half century earlier to land a man safely on the moon.

As with Kennedy's electrifying challenge, Obama's call for national support for electric vehicles created an urgency to realize a broad vision in which technology and science would achieve a landmark that would, in turn, become a manifestation of American pride and achievement. As part of his challenge, Obama pledged \$2.4 billion to research and development of electric vehicles as well as large tax credits to vehicle buyers.

Much as Kennedy's challenge appeared at the time a pipe dream, Obama's vision was almost immediately dismissed as unattainable—although

there existed a promising market for hybrid cars (cars that use gas as well as electricity), all-electric vehicles had accounted for fewer than 1 percent of cars sold that year; even hybrids fared only slightly better (roughly 3 percent). Industry analysts cautiously projected perhaps by 2020 the million car mark might be achieved. But like Kennedy's challenge, Obama's call is perhaps more doable than it might at first appear, more calculated, and far more modest than it might seem. After all, 1.6 million electric vehicles had been sold in the six years before the State of the Union address, of which just under a half million were still in use, and if the vehicles could maintain a modest 1.7 percent of the overall sales of lighter vehicles (which average 15 million units per year in the age of the downsized automobiles and steadily escalating fuel prices), the million vehicles on America's roads was eminently attainable at least near Obama's target year.

In fact, it might be the greater challenge to overcome public misperceptions about the vehicles' range and expense and the usual uneasiness of consumers being introduced to any radically new kind of technology (similar resistance met by personal computers less than a generation earlier). Strident advocates of electric vehicle technology, in fact, considered Obama's national goal, if anything, too timid (European automotive analysts project that by 2025 all vehicles sold in Europe will be electric or minimally hybrid cars). These vocal proponents argue that America must embrace electric vehicles sooner rather than later and, in turn, move decisively toward asserting energy independence at least in the transportation sector and, in so doing, start to bring under control the greenhouse gas emissions from conventional gasoline engines, levels that had, over the last decade, reached alarming, unprecedented levels.

History

Although electric vehicle development appears at the cutting edge of contemporary technologies (in 2010 alone there was a 60 percent spike in the number of patents issued for electric vehicle components), electric vehicle development actually predates hydrocarbon vehicles by nearly half a century. Prototypes were developed beginning in the 1820s in a variety of laboratory workshops in Europe (historians cannot agree on a single clear line of credit for the design). By the early 20th century, in

addition to electric railway systems, electric cars in both Europe and America were ubiquitous, and unlike the contemporary horseless carriages with their internal combustion drive, electric vehicles were valued not only for their speed (they averaged about 20 mph) but also for their clean comfort, their quiet ride, and their easy drivability (in fact, they were often marketed as “women friendly”). Of course, given the relatively brief life of the battery cells at the time, electric vehicles were found most often in cities, and given the few power plants and the general thinness of America’s energy grid, electric vehicles were mostly found in the industrial Northeast corridor.

With the turn of the century oil boom (massive reserves tapped in Texas, Oklahoma, and California) and the national initiative to build an interstate highway system in the century’s first two decades, internal combustion cars (and long-distance driving) became the craze, and the electric vehicle faded from the national consciousness, save for a brief interest during the fuel reserve crises of World War II. In technology-enriched postwar America, innovations in electric vehicles were realized in train and subway systems, golf carts, boats, wheelchairs, and mail trucks, as well as military vehicles and submarines. Perhaps the most notable electric vehicles of the era were the three lunar rovers left behind on the moon by Apollo astronauts. Although the Big Three car companies had divisions investigating electric vehicles as early as the mid-1950s, there was little progress as there was little urgency. That would change dramatically in the mid-1970s when America faced the twin threats of a massive energy crunch from oil dependency on politically unreliable foreign markets and the growing scientific data on the short- and long-term damage hydrocarbon burning caused the atmosphere.

After a brief national embrace during the Clinton boom years of spacious utility vehicles with poor gas efficiency, the global economic recessions of the early 2000s returned attention to the promise of electric vehicles as environmentally aware consumers called for reliable and affordable models. Promoted initially as ideal for short-distance drives, electric vehicles (and the next generation hybrids) quickly gained national attention. By the mid-2000s, numerous corporations who relied on delivery systems (department stores, furniture stores, hotel chains, food producers, package

delivery organizations) had embraced electric vehicle technology. Rental car agencies announced plans to introduce electric vehicles as an option. In the aftermath of Obama’s rallying call for an embrace of electric vehicle technology, General Electric announced its own ambitious program to buy 25,000 electric vehicles for its global fleet, to date the largest single corporation investment in electric vehicle technology.

Types

An electric vehicle is similar to a conventional fossil-fuel burning vehicle save that it is powered by a rack of rechargeable batteries (manuals for the conversion of conventional cars into electric vehicles by amateur car enthusiasts are a booming business). Conversions involve removing from the donor car the engine, the gas tank, the cumbersome exhaust system (electric vehicles are fume free) and installing a complex of lead-acid batteries (usually a dozen 12-volt units); a controller to direct the surges in electricity; and the electric motor itself. There are three types of electric vehicles: (1) those (such as electric train systems) directly powered by actual attachment to a remote external power sources, most often by overhead or underground wiring; (2) plug-in vehicles powered by electricity stored from external sources accessed through conventional wall sockets in rechargeable electric storage systems (the process takes on average six hours); and (3) vehicles actually powered by on-board electric generators or fuel cells.

Trendy hybrid vehicles have found a sales niche, such as the popular Toyota Prius (the first mass-produced electric vehicle in the United States with more than 3 million units sold since its introduction in 2001), the Dodge Dart, the Ford Fusion, and the Volkswagen Jetta, vehicles that use a combination of gasoline and electricity and offer a greater driving range than conventional electric vehicles yet do considerably less damage to the environment.

Benefits and Drawbacks

Certainly the argument in favor of developing electric vehicle technology that most often becomes an applause line for politicians is its promise to help America achieve energy independence. Electricity, after all, is a domestic product. Projections indicate that wide embrace of electric vehicles could reduce foreign oil dependency by as much as 60

percent inside a decade. Of course, it is not that simple. Critics are quick to point out that more than three-quarters of the power plants crucial to providing electric vehicles with their charge, in fact, burn fossil fuels (natural gas and coal). So, they argue, electric cars are in fact burning fossil fuel the same as conventional cars. Advocates counter that such crucial energy production can, and will, ultimately be shifted to renewable energy sources such as nuclear, wind, hydro, and solar power and that given the clean efficiency of the electric engine, even when the energy source is provided by a fossil-fuel power plant, carbon dioxide emissions overall are still cut substantially, nearly in half.

Scientists point out that a far more important advantage of electric vehicles comes from their energy efficiency. Ninety percent of the energy produced by an electric vehicle system is converted to actual work; electric engines do not burn fuel when they idle, and the vehicles have no tail-pipe emission by-product. Climatologists argue that carbon dioxide emissions in the first decade of the 21st century have already reached levels that, a scant generation ago, were considered apocalyptic in their implications. Although other factors have contributed to greenhouse gas effects (deforestation, for instance, and massive power plants), vehicular transportation is responsible for close to 80 percent of emissions. In addition, because they are virtually noiseless, electric vehicles in heavily concentrated urban areas would significantly reduce the aggressive levels of noise pollution, which psychologists have linked to high stress levels, depression, and insomnia.

In addition to environmental impact and energy efficiency, electricity is simply cheaper than gasoline. At 2013 gas prices, a cross-country trip from Washington, D.C., to San Francisco, about 2,500 miles, would cost a little over \$350 in gas; electricity would cost about one-sixth of that (although critics are quick to point out that recharging stops would inevitably impact driving time and consequently expenses). Buying electricity for electric vehicles would be like paying just under 75 cents for a gallon of gas.

Ultimately, proponents of electric vehicles extol the most immediate benefit: the ride itself. The vehicles offer an unparalleled quiet riding environment, unstrained acceleration (although the short quick jump often required for passing can present

problems); and smoother operation on uneven surfaces, tight curves, and wide turns. Given the relatively simple engine construction, maintenance is far easier and engine breakdowns are far less frequent, although loss of power from a tapped battery set is a concern. Repair work is significantly less worrisome, although finding mechanics competent, or even willing, to work on the vehicles can pose a problem.

There are other problems. The current lead-acid battery is bulky and heavy and has a relatively short life—they start to degrade on average after just two years, which means owners could face multiple replacements of battery packs for a single car. Replacing the battery system is prohibitively expensive, as a battery pack averages \$2,200. Advocates, however, quickly point to the sufficiency of the lead-acid battery. If developers of the next generation of electric vehicles are already working on extending the range of the batteries to make electric vehicles long-distance competent, AAA data indicates that currently the average drive distance for most errands is typically about 9 miles, well within the range of lead acid battery technology.

U.S. Department of Transportation data suggests that 80 percent of vehicle owners in America drive, on average, 50 miles or fewer a day. The storage capacity of lead-acid batteries permits between 50 and 100 miles between recharging, and recharging is a matter of plugging in the engine to an external power outlet, a process that can conveniently be done overnight or during the workday with the advent over the last decade of businesses and even cities providing a network of accessible recharging stations (most major European cities already have them or are constructing them). That means that electric vehicles and lead-acid batteries are currently able to meet the demands of ordinary day-to-day driving needs.

By comparison, however, a tank of gas can give a vehicle owner more than twice that range. Electric vehicle owners often fret over losing the vehicle's charge far from a recharging station or far from home (the condition has been termed *range anxiety*). Because even the most diligent owners inevitably neglect basic recharging responsibilities and because recharging is time consuming, the public perception of all-electric vehicles, inevitably, is that they are impractical, good only for local driving, suburban commutes, and limited weekend and

evening errands. They are widely perceived to be a useful second car, a way for upper-income advocates of trendy green causes to endorse electric vehicles without actually depending on them.

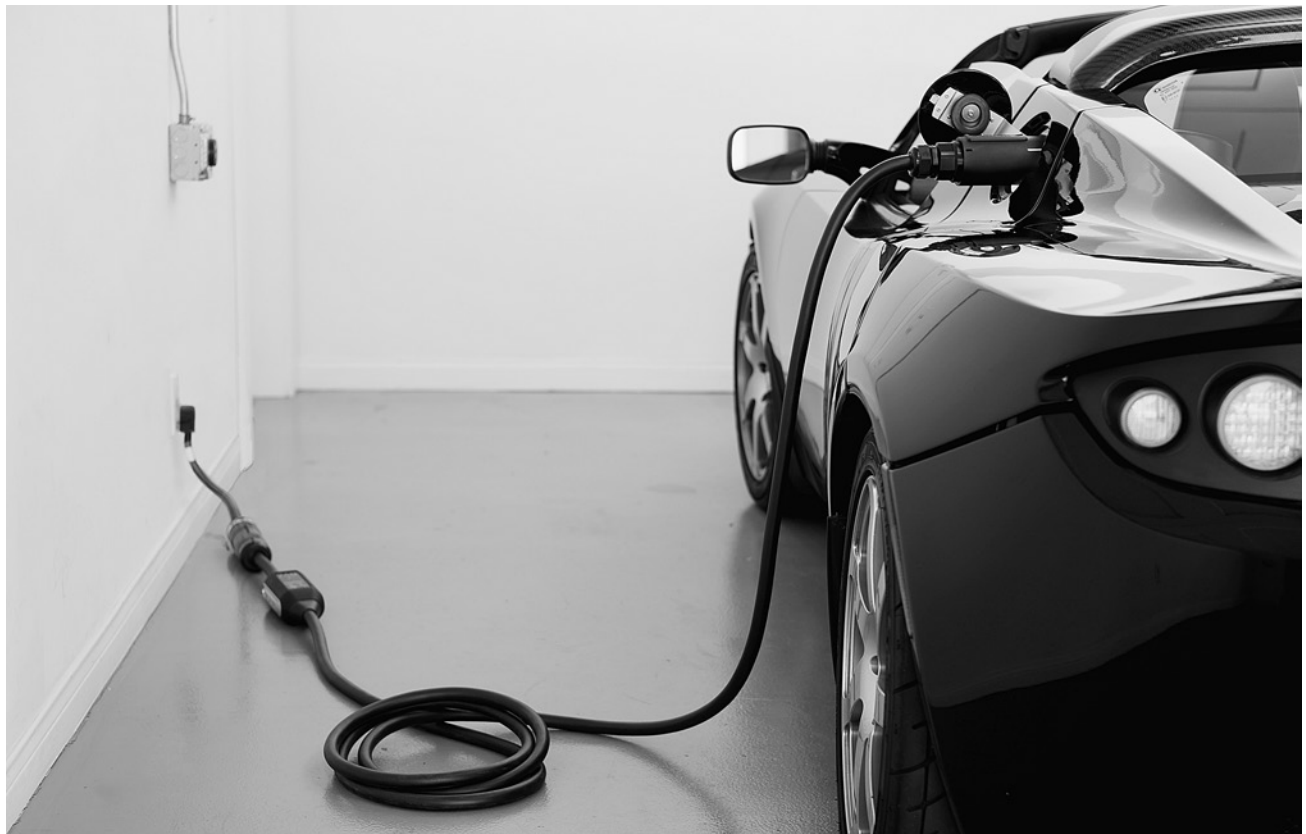
The cars become, in turn, a kind of status symbol or a very public political statement, the car itself more an activist statement than an actual working vehicle. Critics of the government-spurred research glut into marketable electric vehicles point out that urban centers would be far better served by developing fuel-free transportation systems—particularly creating pedestrian incentives, building state of the art biking paths, or investing in all-electric public transportation systems.

Future Developments

Developing long-distance range capability is the primary goal of electric vehicle technology. That hinges on evolving a better battery system. Most promising is the lithium-ion (li-on) battery that

is far lighter than lead acid type, can be fully recharged in under 20 minutes, and can hold the charge far longer, thus promising to extend the range of electric vehicles up to the standard range of a full tank of gas, roughly 300 miles. In the early 2000s, however, lithium-ion battery technology, although central to consumer electronics for years, was considered by transportation industry analysts more than decade off for widespread vehicle use, unworkable for passenger car use. Then the car industry was electrified in 2008 when a modest start-up company in California, Tesla (named for the pioneering electrical engineer Nikola Tesla), unveiled its Roadster, a snazzy two-seat convertible with a lithium-ion battery system. It catapulted the tiny company into global celebrity, and, despite its \$100,000 price tag, the Roadster was a market sensation.

Other models have found similar success, most notably the Nissan LEAF. In late 2013, scientists at



The all-electric Tesla Roadster sells for around \$100,000 and can be recharged from a household electrical outlet if needed. All-electric vehicles made up less than 1 percent of all cars sold in the United States in 2011, while hybrids captured about 3 percent of the market. While electric car sales remain modest, predictions for their use range as high as 8 million vehicles worldwide by 2025.

Germany's Center for Solar Energy and Hydrogen Research announced they had successfully tested a li-on battery that would be capable of providing a vehicle a working charge for more than 25 years.

Although sales of electric vehicles currently lag behind industry expectations and far below the inspirational rhetoric of politicians, electric vehicles are poised to become by necessity a staple in the global car market given the steadily escalating cost of fossil fuel and the growing apprehensions over long-term damage to the environment. Plug-ins, hybrids, and even the high-maintenance all-electric vehicles will claim a growing share of the world vehicle traffic, by some projections more than 8 million on the world's roads by 2025.

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See Also: Aircraft Design; Aircraft Propulsion, New Technologies of; Alternative Automotive Fuels; Alternative Fuels; Automated Road Pricing and Toll Collection Systems; Automated Vehicle Location Systems; Automated Vehicle Monitoring Systems; Automobile Collision; Avoidance Systems; In-Vehicle Computers; Electric Vehicle Recharging Stations; Energy Costs; Gasoline Engines; High Speed Rail, Design and Technology of; Hybrid Automobiles/ Hybrid Electric Vehicles; Hydrogen Fuel Cells; Light Electric Vehicles; Low Emission Vehicles; Maglev Systems; Neighborhood Electric Vehicles; Noise Pollution and Cars; Space Travel, Commercial; Zero-Emissions Vehicles.

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Electronic Route Guidance Systems

In the 1960s, the U.S. government endorsed electronic route guidance systems (ERGS) as the forerunner of a more comprehensive research and development program utilizing intelligent transportation system (ITS). A system integrating advanced technologies such as communication engineering, information theory, and navigation principles, ITS helps make transportation systems more reliable and efficient. Since the 1990s, the ITS field has expanded rapidly and provided traffic advisory information and route guidance to motorists as traffic congestion continues to hamstring modern societies across the world.

Types of Systems

In-vehicle navigation and route guidance systems come with dual purposes—they can be used for navigation and/or following a route. The basic navigation system features a map with the location of a vehicle so that drivers can follow a chosen route to their destinations while route guidance systems provide drivers with specific routing instructions. Systems can also be classified based on their communications with the outside world; they are considered to be autonomous if they continuously self-navigate with no active external communication links and use dead reckoning with radio trilateration (passive reception) and/or map matching. Autonomous systems may also give static route guidance based entirely on internally stored historic map information.

Proximity systems are not considered autonomous, because they need to communicate with a roadside beacon for continuous navigation. Other more sophisticated versions of proximity systems include a one-way communication link to the vehicle from a control center creating the conditions for semi-dynamic route guidance and hazard warning besides static route guidance. This feature allows recent changes in historic road networks to be updated and provides information about prevailing traffic and emergency conditions in the network through area wide or local data radio broadcasting.

Systems with two-way communications or integrated systems create the opportunity for dynamic real-time route guidance for the individual driver, providing responsive routing to the driver's

destination while allowing the driver to make emergency calls. It provides for central monitoring and the command of individual vehicles necessary for traffic and fleet management.

Origins

The origins of electronic route guidance systems can be traced to the mid-1960s when Alan Stephenson Boyd headed a task force that recommended establishing a Department of Transportation to President Lyndon B. Johnson. The new Department of Transportation would include the Federal Aviation Agency, the Bureau of Public Roads, the Coast Guard, the Saint Lawrence Seaway Development Corporation, the Great Lakes Pilotage Association, the Car Service Division of the Interstate Commerce Commission, the subsidy function of the Civil Aeronautics Board, and the Panama Canal.

On March 6, 1966, after he modified the recommendations that the Boyd task force made, President Johnson sent Congress a recommendation urging it to establish a new Department of Transportation with the task of coordinating and managing transportation programs, providing leadership to resolve transportation problems, and to develop national transportation policies and programs.

President Johnson's argument was that America's safety, economic health, and national defense depended on the strong foundation of a modern transportation system, and he acknowledged that although the American transportation system ranked as the best in the world, its operations wasted lives and resources. As President Johnson said, "America today lacks a coordinated transportation system that permits travelers and goods to move conveniently and efficiently from one means of transportation to another, using the best characteristics of each."

On October 15, 1966, President Johnson signed the Department of Transportation enabling act after compromising with Congress and accepting an altered version of his original bill. The newly created U.S. Department of Transportation, Bureau of Public Roads played a pivotal role in creating early electronic route guidance systems.

Early Electronic Route Guidance Systems

During the 1960s and 1970s, the probability of improved driver routing information and controlling and directing the flow of traffic motivated the federal government and private industry to

introduce several experimental in-vehicle route guidance systems. These systems did not provide in-vehicle navigation capability but rather were integrated systems that used interactions with roadside units called proximity beacons to fix vehicle positions and provide ongoing route guidance. During the 1960s, two experimental guidance systems appeared. In the United States, General Motors Corporation developed the Driver Aid Information and Routing System (DAIR), which used different arrangements of magnets in the roadway to identify specific locations throughout the routing network and CB radio for communications.

The Office of Research and Development, Bureau of Public Roads, as part of the U.S. Department of Transportation, developed the second experimental system of the 1960s using electronic equipment in participating vehicles and at intersections to guide motorists, known as an electronic route guidance system. The program focused on the destination of the motorist, with the driver entering a code word as a symbol of his or her destination into the system. As the vehicle approached each intersection equipped with instruments, the instruments transmitted the destination code to the roadside where a stored program decoded it. The program transmitted a routing instruction back to the vehicle and displayed the instruction with a symbol or word message containing the maneuvers the driver should make at the intersection or interchange. In the late 1960s, the government canceled the program because of the projected high cost of the required infrastructure.

During the 1970s, industries developed an array of roadside based systems, including Philco-Ford, a destination coding system, and techniques for solving routing problems. An early map matching system, Automatic Route Control System (ARCS), first appeared in 1971 on a newspaper delivery route, using a differential odometer and a map matching algorithm to correlate measured positions with that on a digitally encoded route map. Few of these systems survived beyond the experimental stages because most of them required an extensive roadside infrastructure to operate and were only cost effective in congested urban areas.

1980s and 1990s Systems

In the 1980s, the major automobile manufacturers and many electronics companies developed a new generation of ERGS with the goal of marketing them

as showroom options or aftermarket accessories. These systems combined several different navigation technologies to form autonomous or self-contained in-vehicle navigation systems mostly based on electronic maps of some kind and were limited by map coverage, although not necessarily map matching. Some of the systems provided drivers with route guidance information to their destinations. Unlike infrastructure-based systems, the user bore the entire cost of ERGS systems. Characteristics of some typical ERGS systems included a range of technologies, performance strengths and weaknesses, and differences in cost and potential marketability.

Contrasted with ERGS systems, map matching systems depended on the supply of accurate maps, which were not always readily available to be digitized, to generate the necessary map database. The digitizing process could be expensive and time consuming and since the road network often changed over time, keeping the map database current was difficult. The various map matching systems reflected the three standard methods of storing map information: photographic, digital image, and digital encoded. Digital encoding, the most sophisticated method, involved digitally encoding the map as a set of intermodal vectors defining each roadway and intersection. The early Honda system used photographic storage, the least sophisticated method, which required the user to slip a transparent map overlay over the CRT. Chrysler used the video image method.

In the 1970s, Bosch/Blaupunkt and Siemens jointly developed the ALI-SCOUT navigation system, which combined a dead reckoning navigator—magnetic compass and differential odometer—with two infrared communicators between a vehicle and the roadside. Rather than storing a large map in the vehicle, the navigation system fed a digitally encoded map covering the immediate surrounding area into each vehicle as it passed a beacon. It also included recommendations about traffic conditions.

Founded in 1983 in California, Etak Inc. pioneered commercialized automotive navigation systems and digital mapping technologies that became standard in vehicles in later decades. In 1985, Etak introduced the Navigator, its flagship system, which is the ancestor of many modern GPS-based automotive navigation systems.

The first commercially available automotive navigation system using map matching technology,

the Etak Navigator used a flux gate magnetic compass and a differential odometer for dead reckoning information and stored the digital map data on magnetic tape. At the start of the trip, the driver entered origin-to-destination information and the system continuously tracked the location of the vehicle and its surroundings on a CRT map display. A stationary arrowhead in the center of the CRT screen pinpointed the vehicle position and a star marked the vehicle's destination on the map. As the vehicle traveled along, the map moved with the arrowhead so that the map always showed the same view of the roadway as the driver saw ahead of the vehicle. Etak claimed navigation accuracy of better than 100 feet. General Motors Corporation bought the North American rights to Etak technology, although other companies in America and abroad developed similar systems. The CD ROM's capacity to store massive map databases, including a digital map of every highway and street in the United States and Canada, forecast a promising future for Etak technology.

Global Positioning System Satellites

Four generations of GPS satellites have operated since 1940, when the idea for a global positioning/navigator system was first introduced. The U.S. Air Force developed global positioning technology, and then civilian companies gradually adapted it to commercial use. Operated by the 50th Space Wing of the Air Force, the Global Positioning System (GPS) satellite network provides target information to military forces around the world, but it also guides individual civilian vehicles on their daily journeys.

The GPS Space part of the system features six orbital sectors that require at least four satellites in each to operate. The control system has monitoring stations in Hawai'i, Kwajalein, Ascension Island, Diego Garcia, and Colorado Springs and three ground antennas at Ascension Island, Diego Garcia, and Kwajalein. A Master Control station is located at Schriever AFB in Colorado. The NAVSTAR GPS Joint Program Office at the Space and Missile Systems Center at the Los Angeles Air Force Base in California manages the NAVSTAR Global Positioning System.

NAVSTAR

In 1973, the Pentagon proposed a global positioning satellite system eventually called NAVSTAR,

in response to the military necessity of delivering weapons on target and reversing the growth of navigation systems in the U.S. military. The creators of NAVSTAR designed the system to operate with at least 24 satellites in orbit, and the Air Force launched the first generation of NAVSTAR satellites in 1978. The U.S. Department of Defense immediately recognized the significance of GPS to civilians around the world, and in 1989, the first full-fledged GPS satellites were launched, designed to operate 14 days without any input from the control systems on the ground. Between 1989 and 1990, the Air Force launched nine more satellites.

In June 1993, the last of the 24 GPS satellites went into orbit, finishing a satellite network that could provide position data to locate a vehicle within a 98-foot range anywhere on earth. The satellites, which transmit timing signals and position data, carry as many as four cesium and rubidium atomic clocks that the ground station in Colorado periodically updates. A GPS receiver, which may be a small, hand-held instrument, decodes timing signals from several of the satellites, translating the arrival times in terms of latitude, longitude, and altitude with a margin of error that can range as small as 33 feet. The satellites orbit about 11,000 miles above the Earth with orbit periods of about 10 hours.

In 2000, President Bill Clinton advanced civilian uses of the GPS system when he ordered the Pentagon to stop manipulating factors, including orbital data and the frequency of the satellite's clock, in a policy called "selective availability," which gave the military optimum advantages. After the terrorist attacks on New York City's World Trade Center and on the Pentagon in Washington, D.C., on September 11, 2001, civilians thought that the Pentagon would reinstate "selective availability," but the Interagency GPS Executive Board reported no change. Following the advice of the Department of Defense, President George W. Bush in 2007 decreed that the NAVSTAR III generation would not feature selective availability at all.

The Air Force has improved NAVSTAR satellites over the generations, and the current versions have an estimated life of 12 years and faster processing power. The Air Force has launched three NAVSTAR 2-F systems, with the latest one in 2012. According to manufacturer Lockheed Martin, the next GPS generation called GPS III will be three times more accurate and will come equipped with

an "antijam" security system. The Air Force could order at least 32 of the Lockheed Martin GPSIII satellites, which are scheduled to launch in 2014–15 and are expected to last for 15 years or more.

Other countries, including Russia and several in Europe, have built similar systems to GPS for civilian and military use, and NAVSTAR is working to meet the competition by improving the accuracy of its system. According to the Federal Aviation Administration, current GPS systems are accurate to within 40 feet and military systems pinpoint within a few inches.

Conclusion

The vision of researchers and entrepreneurs for the future of ERGS includes expanded and increasingly sophisticated hardware and software for static and dynamic systems. Plans include a highway transportation subsystem that focuses on the driver as an integral part of the system but will enhance the driver's performance by removing much of the route responsibility and focusing more attention on the driver's primary task of controlling the vehicle. Adding central control facilities and communications links to intersections may also permit more uniform distribution of traffic over the highway network.

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See Also: Automated Vehicle Guidance Systems; GPS; GPS, Automobile; Intelligent Transportation Systems; Smart Cars.

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Emergency Response Systems

Naturally occurring and human-made emergencies occur every day on roadways. Emergencies on roadways may be caused by multiple automobile accidents, fires, earthquakes, landslides, radiation release, flooding, snow, ice, and chemical spills. The impacts of these events may be limited to a road intersection or affect large sections of a road network within the surrounding region. Emergency response systems provide a mechanism for emergency services to receive notification of incidents, allocate and prioritize resources, and respond to emergencies.

Emergency response systems were developed to facilitate notification and assist emergency response personnel when responding to emergencies or crises. Some of these systems are centrally monitored and provide a mechanism for emergency managers and organizations to manage and allocate resources during emergency or crisis responses. Automobiles or highways may be equipped with automated sensors that notify emergency response systems when and where an incident has occurred.

Over the years, emergency response systems have transitioned from analog phone communications to mobile and computer-based phones and sensors. As urban populations continue to increase, road networks are becoming more and more congested, leading to increased numbers of emergencies. Technologies and methods for responding to emergencies have improved as a result. Several types of emergency response systems exist on roads, including hazardous materials response systems and automobile response systems for vehicle breakdowns and accidents. Notifications for these systems may occur through the 911 Emergency Response System, intelligent transportation systems, or automated notification systems. Emergency services, such as police, fire, and ambulance, support the response systems, depending on the type of event. During response to an incident site, agencies can use the Incident Command System as a framework for managing and coordinating resources from various agencies.

Resources

Many resources are used in support of emergency response systems. Real-time data, such

as aggregated cell phone location data and road conditions, provide up-to-date information on where citizens are located and where authorities may need to respond. Remotely sensed data, such as aerial and satellite imagery and closed circuit television (CCTV), provide planners with visual information that can be integrated into emergency response planning. For example, recent satellite imagery may provide information on a new subdivision or retail establishment that was built in an incident area. CCTV is often used to determine which citizens are responding to instructions from emergency managers.

Often, geographic information systems (GIS) are used to assist with planning and allocation of resources. Crisis resources are often geographically dispersed, including police, fire, emergency medical services (EMS), hazardous materials (HAZMAT) response, and airborne assets (helicopter, plane, and unmanned aerial systems). GIS provides a toolset that can track assets and their locations and provide estimated arrival times to an incident. GIS is frequently used to analyze data to support emergency response. When an incident is identified, GIS provides tools to identify at-risk areas that emergency response personnel need to prioritize for notification and allocation of resources. GIS enables emergency response personnel to analyze citizens' locations, identify the status of the road network, and determine the optimal evacuation route that minimizes risk to citizens as they evacuate. With proper coordination from authorities, GIS data and analysis can be shared among agencies on desktop computers, laptops, tablets, and mobile phones.

It is imperative that planning for access to resources occurs prior to an incident. Coordination between adjacent jurisdictions for data sharing is just as important as mutual aid support. Agencies should ensure that in emergencies, data and analysis can be shared with adjacent jurisdictions without contract violations (for example, sharing remotely sensed imagery with other agencies to support their planning and response). Joint exercises and training for support personnel that involves personnel from other jurisdictions can assist with identifying problems that involve both jurisdictions, prior to an incident occurring. Joint exercises and training also assist with building trust and minimizing conflicts during an event.



Iowa Army Guardsmen assisted in rescuing the driver of this disabled car during a severe snowstorm in Iowa City, Iowa, February 1, 2011. Emergency response systems may eventually be able to make use of both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. Data would be provided by each vehicle within the network of wirelessly connected automobiles to the transportation network, allowing other drivers to change routes and giving emergency responders advance details about incidents.

Hazardous Materials Response Systems

Emergency response systems on roadways include systems for responding to hazardous materials (HAZMAT) spills, accidents, and vehicle breakdowns. Planning and response for each of these events may involve federal, state, and local agencies and resources. Various chemicals, including toxic waste, radioactive materials, gasoline, oils, and gases are transported on highways every day. Occasionally, a transport vehicle is involved in an accident or has a leak or spill. Specially trained personnel are needed during response to HAZMAT incidents to identify the material and the impact to the surrounding area. HAZMAT-trained personnel work in coordination with other agencies to secure the site and notify any personnel in the danger zone where to evacuate. Emergency response systems enable planners to identify the footprint of the danger zone, who is affected, and what additional resources are needed to safely evacuate the area and clean up the spill.

Manual and Automated Notification Systems

Traditional emergency notification involved an individual calling 911 and reaching a 911 operator. Universal emergency response systems, such as 911, were initially developed with land-line communication and eventually adapted to support mobile phones. Current 911 calls can be geolocated to a mobile phone tower or an area within the mobile phone tower footprint. To improve support to mobile phone customers during emergencies, mobile phone companies and the Federal Communications Commission are working to establish “text-to-911” and enhanced geolocation capabilities that provide the latitude and longitude of mobile calls.

During the past two decades, automobiles have added sensor technologies that automatically detect when a vehicle is involved in an accident (for example, when the automobile’s air bags are deployed or the vehicle is in a collision). Automated

emergency notification systems, such as OnStar (United States) or eCall (European Union), relay messages to emergency services through automated and manual methods. For example, with OnStar, when a vehicle is involved in an accident, an OnStar-trained adviser communicates with the driver and passengers. If assistance is requested or there is no answer, the adviser sends a request to 911. The OnStar system provides the adviser with the vehicle's global positioning system (GPS) location, which is shared with emergency personnel. The vehicle also transmits direction and number of impacts, rollover status, and maximum velocity at impact. OnStar advisers share this information with first responders prior to their arrival, providing them with a measure of the severity of the accident. These systems also offer methods to manually request assistance or share information during a disaster or emergency.

The future of emergency response systems includes vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. Automobiles, enabled with vehicle-to-vehicle communications transfer and receive information from other vehicles, whereas automobiles enabled with vehicle-to-infrastructure communications transfer and receive information from roadside units, Wi-Fi, mobile phone towers, or satellites.

Wireless access in vehicular environments (WAVE) includes V2I and V2V communications. As WAVE is implemented, each vehicle within the network of wirelessly connected automobiles provides data to the transportation network (vehicle location, speed, etc.). This data enables other vehicles to change routes due to congestion, vehicle accidents, and other hazards along a section of highway. WAVE also provides additional information to emergency response personnel, such as the severity of the incident, number of vehicles involved, and the appropriate resources to use in the response (for example, fire, EMS, police, and HAZMAT).

The Incident Command System

The Incident Command System (ICS), which is a component of the U.S. National Incident Management System (NIMS), is an emergency response system that integrates equipment, personnel, facilities, communications, and procedures in a common organizational structure. ICS is a standardized system that is used at the site of an

incident and supports all types of hazards. During a response, ICS provides a hierarchical, top-down framework that enhances coordination between different jurisdictions and agencies.

The incident commander is responsible for the incident and is supported by section chiefs. The makeup of the sections is dictated by the type, duration, and scale of the incident. Section chiefs include but are not limited to operations, logistics, plans, and finance. The incident commander may also be supported by a public information officer and a safety officer. ICS provides a standard process for planning and managing resources. This ensures that when local agencies are overwhelmed or under-resourced for an incident, state and federal agencies can provide additional resources as needed to support local authorities.

Regional Emergency Response Systems

Similar to some systems used in military operations, regional emergency response systems such as Operational Situational Preparedness for Responding to Emergency (OSPRED) and Regional Integrated Transportation Information System (RITIS) provide a common operational picture (COP) of transportation networks in metropolitan areas. These systems are tailored to support the needs of multiple agencies (for example, HAZMAT teams, transportation departments, first responders, and others) within a transportation region.

OSPRED is an Internet-based map developed for the Maryland Emergency Management Agency. OSPRED provides situational awareness for numerous types of events, including floods, power outages, open shelters, hurricane tracks, weather watches and warnings to police and fire stations. Real-time data include weather radar, CCTV, traffic conditions (speed, congestion, incidents, and active restrictions). Information is shared through an open standard with the National Capital Region.

RITIS is similar to OSPRED; however, RITIS provides, fuses, and disseminates information (traffic, events, parking, weather, signals, transit, and computer-aided dispatch) from Delaware, Maryland, Pennsylvania, Virginia, Washington, D.C., and West Virginia. Numerous federal users (U.S. Secret Service, U.S. Capitol and Park Police, Federal Emergency Management Agency, U.S. Army and Air Force, Northern Command, and the National Security Agency) use RITIS.

Emergency Response Systems Coordination

The importance of emergency response systems is readily apparent during a large-scale natural or technological disaster. However, a lack of coordination and planning prior to an incident can result in communication challenges, lack of information sharing, and failed response from multiple agencies. For example, are data formats compatible and can data be readily shared with other agencies or jurisdictions? Do other agencies have people who are properly trained to use the data, software, or resources needed during an incident? Prior coordination, collaborative training, and exercises often identify challenges emergency planners and decision makers may face during a real-world event.

Social Media

Social media such as Twitter and Facebook have been increasingly used by emergency operations centers to increase awareness in many regions, especially urban and suburban communities. In conjunction with other notification networks, such as radio, TV, and wireless emergency alerts (WEA), social media provide an alternative means of informing the public and news media of events in a region.

Emergency response systems provide enhanced situational awareness to citizens and emergency response personnel. Additional research on emergency response systems, including the continued integration of geographic information systems and multiple methods of communication (for example, social media, radio, TV, Internet, and WEA), will enhance coordination and response to emergency incidents occurring along transportation networks. Although OSPREY and RITIS provide enhanced awareness of road networks, they lack situational awareness of rail corridors within the regions of concern. Road networks are often severely impacted by emergencies along rail networks, either directly or indirectly. The addition of rail transportation networks to these systems would enhance situational awareness of cargo and passenger transport within these regions and provide planners with insight into possible impacts to transportation networks during an emergency.

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See Also: Automated Vehicle Monitoring Systems; Emergency Transportation Planning and Operations; Emergency Vehicles; Emerging Technologies; Evacuation Planning; Geographic Information Systems in Transportation; Highway and Road Safety; Incident Detection Systems, Automobiles; Intelligent Transportation Systems; Intelligent Vehicle Highway Systems; Traffic Incident Management.

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Emergency Transportation Planning and Operations

There is a strong need for emergency transportation policies and oversight from the federal government. Over 400 tropical storms, hurricanes, tornadoes, acts of terrorism, and accidents involving hazardous material occur each year that require emergency response and may even require the evacuation of the public. These, in addition to other extreme weather, wildfires, multivehicle crashes, and potential security threats, require the United States to be prepared for anything and everything. Responders must reach the scene, victims must evacuate the danger zone, and clearance and recovery resources must arrive on time.

The U.S. Department of Transportation's Federal Highway Administration (FHWA) oversees the Emergency Transportation Operations (ETO) department within the Office of Operation. This program maintains policies and procedures for disasters, traffic planning for special events, and traffic incident management programs.

The FHWA provides tools, guidance, and best practices that aid local and state Departments of Transportation (DOTs) and their partners in their efforts to improve transportation efficiency and responder safety when a nonrecurring event interrupts transportation operations. Nonrecurring events include out of the ordinary traffic incidents, such as planning for a special event or disaster or emergency transportation operations, referred to as Disaster ETO. Partnerships in ETO program areas involve nontraditional transportation stakeholders, such as public safety management organizations including fire, rescue, and emergency medical services.

Emergency Shelters and Evacuations

Emergency Operations Centers (EOCs) are activated once a threat or risk of an emergency is established. EOCs can be established by the state or local government, although there is often miscommunication in terms of policy as to which department activates the EOC. There is not a clear connection between the Homeland Security Advisory System (HSAS) and the decision to activate an EOC. Most

are created at the city, county, or state level. Coordination across state boundaries for widespread emergencies is a challenge, although efforts are continuing to improve communication and coordination policies.

In major cities, emergency evacuation routes are designated in the event of an emergency or hazardous weather conditions. However, many regions still do not have such routes designated. Some cities and towns have identified traffic detour routes for road closures due to vehicle crashes, preplanned special events, and construction.

Very often, even the most extensive emergency evacuation plans are not coordinated across county lines or state boundaries, which makes routing systems incomplete and inconsistent. In some regions, the state highway operators and local agencies have not agreed upon plans to divert traffic from highways onto local streets. Another issue that emerges is the lack of traffic operations controls, including alternative traffic signal timing plans on local streets to accommodate such diversions.

Areas that do have developed emergency or evacuation plans often feel that these plans have not been adequately tested and exercised. Another factor is the weight and size of the vehicles utilizing the route. For instance, a large truck may not be able to pass a road with low overheads or its weight may surpass the allowed road limit on a particular route.

Emergency Resource Management

During emergencies, state and local resources operate at maximum capacity to respond to the emergency while maintaining other services as usual. Currently, no system is in place to determine how these resources should be allocated to the emergency while still maintaining resources for routine response capability. Although many state DOT personnel have experience in responding to emergencies, most indicate that they have had limited formal training in regional emergency response exercises and looking for suspicious activity. This lack of training impacts emergency preparedness and makes emergency planning difficult on such issues as prepositioning resources.

Because DOT personnel do not necessarily have identifiable uniforms or badges, they are difficult to spot initially during a crisis. This is especially problematic when there is a large-scale special event with assistance from many responders from multiple

agencies and regions; such events require security to be tightly controlled. In these cases, DOT-issued responder identification may not be recognized as adequate. DOT first responders need to participate in regional public safety or national first responder identification programs to ensure they are qualified to assist outside their local region. In addition to a lack of identifiable uniforms or badges, DOTs often lack enough professional personnel who can properly assess damage at the scene and the costs associated with it.

Although it is difficult to plan ahead for unimaginable events, natural disasters and terrorist attacks do occur and it is important to have a plan in place so local resources are not exhausted shortly after the incident when help is needed the most. Many regions are not fully prepared to handle mass casualties and may not have established procedures or locations to handle victims of the emergency. In the instance of a terrorist attack, some regions have expressed concern that shelter sites may become secondary terrorist targets because of the large concentration of people there.

Contracts between federal and local transportation operators and towing companies enable rapid clearance of individual incidents. This is especially critical when many vehicles may be damaged or abandoned, blocking emergency traffic.

Emergency Transportation Policy

When planning for an emergency, transportation planning agencies, such as state DOTs, may be able to funnel funding to certain emergency response activities and provide funding for evacuation planning, road improvements, and other elements that can be important in emergency response. Furthermore, the transportation planning agencies have traffic insight that can be vital in emergency route planning.

In terms of parking, several DOTs allow vehicle parking under transportation bridges and overpasses, including those in the interstate system. This is necessary in many urban areas that lack alternative parking facilities. Most regions lack a comprehensive policy addressing parking under transportation facilities, despite the potential dangers it poses.

Most transportation officials are aware of who has the authority to close roads in the event of an emergency within their state, although they are unclear as to whom to turn to when issues cross over into another jurisdiction. In almost all areas, the enforcement of a

quarantine was identified as problematic. Although clear authority to enact quarantines is assigned in all regions, very few cities and counties have plans or procedures for enforcing quarantines.

Communications between transportation agencies and law enforcement agencies on every level must be considered when assessing vulnerability of infrastructure or a region susceptible to terrorist attack. While many of these procedures have been evaluated, their findings have not been shared with other authorities called in during such events. Not only must they be shared but they also must be coordinated to allow for seamless integration in the event of an emergency.

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See Also: Evacuation Planning; Federal Transportation Policy; Regional Transportation Planning; Regional Transportation Planning Organizations; Regional Transportation Plans; Security, Transportation.

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Emergency Vehicles

An emergency vehicle is any vehicle operated by emergency personnel in response to a situation that may cause injury, loss of life, or damage to property. Generally, emergency vehicles include those driven by law enforcement agencies, those driven by fire and rescue services, those operated by emergency



Emergency vehicles typically display retroreflective and fluorescent markings that make them more visible to motorists. Between 1999 and 2009, more than one emergency worker per month was killed while aiding a motorist by the side of the road.

medical service providers (public and private), and the vehicles of towing and recovery service providers. Conventionally, such vehicles are equipped with lights and sirens and are visibly marked as affiliated with the authorizing agency.

Each state defines “emergency vehicle” within its legal codes, and these definitions vary considerably, ranging from any vehicle operated by public police, fire, or airport security agencies or designated as an emergency vehicle by a federal agency to a lengthy list that also includes park rangers, conservation agents, and civil defense authorities. Road rules governing emergency vehicles also vary by state. Because emergency vehicles in operation create an increased risk to those in the vehicle and to others on the roadways, safety of emergency personnel and of the general public is a national concern.

Costly Accidents

Between 1999 and 2009, more than one emergency worker per month was killed while aiding a motorist by the side of the road. More law enforcement officers

were killed in traffic-related incidents than from any other cause between 1998 and 2008. Seventy-one officers died in vehicle crashes or from being struck by a vehicle in 2008. From 2004 to 2006, 37,655 law enforcement injuries from crashes were reported.

Statistics for firefighters reveal the same pattern. From 1996 to 2007, vehicle collisions claimed the lives of 257 firefighters and another 53 firefighters died as a result of being struck by a vehicle. On average, about 25 percent of all firefighter fatalities are response or roadway scene related. One study estimates a fatality rate of 12.7 per 100,000 workers among emergency medical services (EMS) workers.

In addition to the loss of life, emergency vehicle accidents result in delayed emergency service, which can result in further loss of life. For example, a one-minute delay can drop the chance of survival for a cardiac arrest patient from 80 percent to 30 to 40 percent. Vehicle replacement runs from a low of \$40,000 for a high-performance police car to more than \$750,000 for a fire truck. Even more costly, lawsuits can strain the resources of already overburdened local governments.

Improving Safety

Emergency vehicles typically include warning lights, sirens and horns, and retroreflective striping, which reflects light back to its source. These features are designed to make other drivers aware of the size, speed, and location of emergency vehicles. Yet both the number of accidents and the average response time show that traditional measures are not fully effective. Research suggests that speeding to the scene of an emergency endangers drivers and occupants of emergency vehicles as well as other vehicles on the road and does little to improve aid or response time. One study concluded that lights and sirens saved about a minute off the average response time.

The U.S. Fire Administration and the Society of Automotive Engineers conducted a two-part study funded by the National Institute of Justice in 2003 and 2005 that examined the use of warning lights. Based on their findings, the researchers recommended three changes in the way emergency vehicles use warning lights. Because warning lights that are visible at night may be significantly less visible in daylight, they recommended increasing the current intensity of warning lights sufficiently to attract the attention of daytime drivers, or even better, that two levels of light intensity be used. Blue lights proved

more effective than red or amber at drawing attention to vehicles in both day and night tests. They also recommended using different colored lights to make a clear visual distinction between vehicles parked in the normal path of traffic and vehicles that may be near the normal path of traffic but are not obstructing it.

The Standard for Automotive Fire Apparatus of the National Fire Protection Association (NFPA) requires fire trucks and ambulances in the United States to have retroreflective striping and markings in multiple locations. Compliance with the NFPA standard is not mandatory, but vehicle manufacturers generally comply. Although law enforcement lacks a similar national standard, many law enforcement agencies use retroreflective markings on vehicles. Because stealth may sometimes be a priority for law enforcement, high visibility is not always appropriate.

A separate study looked specifically at retroreflective striping, high-visibility paint, built-in lighting, and other reflectors on emergency vehicles. The researchers found that retroreflective materials can aid in increasing visibility of emergency vehicles (especially at night), contrasting colors can help civilian drivers see a hazard, and fluorescent colors (especially fluorescent yellow-green and orange) yield higher visibility for daytime motorists. The researchers recommended improvements that included using retroreflective material to outline an emergency vehicle with “contour” or “edge” markings, especially on large vehicles; placing retroreflective material lower on emergency vehicles to take advantage of headlights from approaching vehicles, using fluorescent retroreflective material for maximum visibility during day and nighttime hours, and applying distinctive logos or emblems made with retroreflective material to improve both visibility and recognition of emergency vehicles.

The “Move Over” Law

Section 2014 of the 2005 Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), titled First Responder Roadside Vehicle Safety, required the National Highway Traffic Safety Administration (NHTSA) to develop a program to address the safety of first responders. One of the things NHTSA did was to work closely with the National Conference of State Legislatures (NCSL) and the National Committee on Uniform

Traffic Laws and Ordinances (NCUTLO) to develop a model “move over” law. In 2012, Hawai‘i became the 50th state to pass a move over law, requiring motorists who are approaching an emergency vehicle on the side of the road with its emergency lights flashing to move over into the opposite lane or to slow down—in some cases to 20 miles per hour below the posted speed limit—if moving over is not possible. Each state has its own penalties for those who fail to comply. These include fines from \$40 to \$500, points on the offender’s driving record, license suspension, or even jail time. Polls indicate that 90 percent of Americans believe traffic stops and roadside emergencies are dangerous for law enforcement and first responders.

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See Also: Automobile Accidents and Prevention; Emergency Response Systems; Emergency Transportation Planning and Operations; Highway and Road Safety; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Traffic Incident Management.

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Emerging Technologies

Within the field of transportation, the term *emerging technologies* typically refers to those technologies that are being developed in order to help people move faster, at greater volumes, or with greater



A manager at NASA's Marshall Space Flight Center's Interstellar Propulsion Research Center holds a sample of a light, rigid carbon fiber material for use in a solar sail, which could harness pressure from radiation to propel spacecraft. The material's density is less than one-tenth of an ounce per square yard.

efficiency. In all fields, emerging technologies represent progressive developments that emerge within a field, typically for competitive advantage. Because of their newness, some of these technologies may seem ridiculous. This is the stuff of the future, but what previous generations may have called ridiculous is now part of everyday life. Within the field of transportation, these advances and innovations can range from bicycle technology to interstellar travel. Some of the most promising currently emerging technologies include those in the fields of automobiles, trains, aviation, and space travel.

Automobiles

Innovations in automobiles are typically concerned with fuel efficiency but may include other areas where the standard automobile is less than optimal. One such innovation that has been of great interest is the airless tire. Such nonpneumatic tires (NPT) would not be supported by air pressure. This type of

tire has already been developed for some vehicles, such as riding lawn mowers, golf carts, and backhoes. Unfortunately, nonpneumatic tires typically provide less suspension and less heat dissipation; either of these features currently make nonpneumatic tires unusable for automobiles. The primary areas of research toward solving these problems focus on the development of new polymers that may be able to better absorb shocks and dissipate heat created by the friction of use.

Driverless cars have also been of interest to automotive innovators. Google has been the most recent corporation to take interest. Google recently won awards from the Department of Defense for its development of a particularly promising driverless car. Until recently, these innovations were somewhat irrelevant as U.S. laws forbade the use of driverless cars on American roads. However, laws passed since 2011 in multiple states allow for the use of driverless cars.

By far, the area of greatest interest within emerging automotive technologies is that of alternative fuel vehicles. These technologies are needed to prepare for the inevitability of peak oil, the point at which the rate of petroleum extraction reaches the maximum and after which the rate of production is expected to reach terminal decline. While the situation is dire, these technologies have been difficult to adopt due to industry resistance and the substantial infrastructure adjustments needed to adopt them. Denatured ethanol mixes have already been used in the United States to some success. The two most common blends are E15 and E85. E15 is made up of 15 percent ethanol and 85 percent gasoline. The major advantage of this blend is that it can be used in any automobile made after 2001, and it is already widely available. E85 is made up of 85 percent ethanol and 15 percent gasoline. E85 can only be used in specially designed flex-fuel vehicles, but it is also widely available in the United States. Diesel has long been preferred over gasoline for its greater fuel efficiency; biodiesel, which is typically made from vegetable fat, has the added advantage of being derived from renewable resources. Electric automobiles are also of interest, as they allow for the use of energy as clean as is available on private or public energy grids. Other nonpetroleum fuels that have been explored include hydrogen fuel cells, steam, charcoal, ammonia, and dimethyl ether.

Aviation and Trains

Aviation innovation tends to focus on going very far distances quickly. Supersonic flight has been of interest to aviators since the mid-20th century. However, supersonic flight causes sonic booms that can be disruptive to neighboring communities and wildlife. Within the realm of supersonic flight, the scramjet, which is a supersonic combustion ramjet, allows for sustained propelled hypersonic flight that could travel any place on Earth in 90 minutes. While this technology has existed since the 1950s, it has only recently become more viable for military or civilian use.

Emerging technologies in locomotives are primarily focused on technologies that will mechanically simplify the track and increase speed. Hovertrains achieve these goals by replacing conventional steel wheels with hovercraft lift pads. This eliminates rolling resistance, thus allowing for very high speed while simplifying infrastructure. Similarly, maglev trains use magnetic levitation to raise trains above the track and propel them with incredibly strong magnets instead of wheels. Like hovertrains, these mechanically simplify the cars while increasing speed.

Space Travel

Among the most exciting experimental space technologies are space elevators, solar sails, and ion thrust engines. Space elevators have been proposed as a means to take personnel and materials into space without the need for massive engines or breaking the Earth's gravitational pull. A space elevator would consist of an orbital station attached to the Earth with a cable composed of very strong advanced materials, likely engineered on the molecular scale. Solar sails and ion thrust engines are proposed methods that could potentially make it possible to travel between stars. Solar sails are made of ultrathin mirrors; these sails would be propelled using radiation pressure to reach very fast speeds gradually. Ion thrust engines are a type of technology that is currently being developed to accelerate spacecraft via electric propulsion.

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See Also: Aircraft Propulsion, New Technologies of; Alternative Fuels; Automated Road-Pricing and Toll-

Collection Systems; Automated Vehicle Guidance Systems; Automated Vehicle Location Systems; Automated Vehicle Monitoring Systems; Economic Development; Electric Vehicles; FreedomCAR and Vehicle Technologies Program; High Speed Rail, Design and Technology of; Hybrid Automobiles/Hybrid Electric Vehicles; Hydrogen Fuel Cells; Hypersonic Flight; In-Vehicle Computers; Low-Emission Vehicles; Maglev Systems; Space Travel, Commercial; Zero-Emissions Vehicles.

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Emissions Modeling

Transportation is a major contributor of greenhouse gas and pollutant emissions. Among the various transportation modes, on-road motor vehicles are the most significant sources of transportation-related emissions. The ability to model emissions from these sources is essential in making informed decisions on transportation programs and investments as well as in forming sustainable transportation and climate change policies.

Modeling vehicle emissions can range from a simple exercise to a complicated task. The choice of the modeling approach depends on the purpose of the analysis, the available data and tools, and

the level of accuracy expected. Different modeling approaches have their own strengths and limitations and are suitable for answering different types of policy questions.

Needs for Emissions Modeling

There are several needs for the modeling of transportation-related emissions in planning and policy analysis. In a broad sense, emissions modeling is conducted to develop emissions inventories. Historical and current emissions inventories are used by policy makers to assess emissions trends, understand the contribution of each emission source, develop strategies to reduce emissions, and track progress over time. Future emissions inventory forecasts are used to assist in the selection of appropriate emissions reduction strategies and to establish emissions reduction goals.

In the context of planning, emissions modeling is performed by transportation agencies to evaluate the potential impacts of transportation plans, programs, and projects on air quality in their areas. In the United States, this is required of agencies in nonattainment areas, which do not meet one or more of the National Ambient Air Quality Standards (NAAQS). The requirement, referred to as transportation conformity, aims to ensure that federal funding and approval are given to highway and transit projects that will not lead to new air quality violations, worsen existing violations, or delay the ability of an area to attain the standards.

Some transportation policies are partly driven by the desire to reduce emissions from on-road motor vehicles. For example, U.S. federal policies encourage construction of high occupancy vehicle lanes instead of general-purpose lanes in nonattainment areas. Many policies that are aimed at reducing traffic congestion also have a cobenefit of reducing traffic emissions. Examples include congestion pricing, car sharing, transit improvement, etc. Emissions modeling can be performed to analyze the emissions reduction benefits of these policies.

In addition, emissions modeling can play a role in the analysis of policies related to other issues as well as transportation. For example, emissions modeling is one of the key modeling steps required to determine the level of transportation-related air pollution near roadways. The modeling results can have implications for public health and land use policies. For example, sites with a high fraction of

sensitive populations, such as schools and nursing homes, should be located far enough away from major highways.

Macroscopic Approach

Emissions from transportation sources can be modeled in many ways. For modeling at the macroscopic level, data input requirements are minimal and the modeling approach is not sophisticated. On the other hand, modeling results are sensitive to only a limited set of variables, which limits the range of policy questions that can be addressed. For example, at the national or state level a spreadsheet tool can be used to model carbon dioxide emissions based on fuel sale records. However, this method will not reveal, for instance, whether the reduction in carbon dioxide emissions is a result of reduction in vehicle miles traveled or improvement in vehicle fuel efficiency.

At the regional level, areawide analysis tools can be used to estimate average emission results for a region. For example, TCM Tools is a sketch-planning tool designed to estimate the change in vehicle activity and emissions resulting from a wide range of transportation control measures such as implementing flexible work hours and improving transit services in the region. The tool provides emission estimates at the regional or areawide level. It cannot estimate emission impacts for specific roadways or locations in the region.

Mesoscopic Approach

Unlike the macroscopic approach, the mesoscopic emissions modeling approach can relate changes in vehicle fleet mix and travel behaviors to the resulting emission changes. It involves determining the amount of vehicle activity (for example, miles traveled or hours operated) and the corresponding vehicle emissions rates (for example, grams per mile or grams per hour). As vehicle emission rates vary by a number of factors, including vehicle characteristics (vehicle type, engine technology, etc.), roadway characteristics (road type, road slope, etc.), and traffic conditions (speed, congestion level, etc.), vehicle activity would need to be characterized by these factors as well.

As an example, carbon dioxide emission rates (per unit distance) of cars and trucks vary greatly by travel speeds. They are lowest at the moderate speeds of 35 to 50 miles per hour and higher at

lower and higher speeds. Modelers need to determine the number of miles that vehicles travel at different speeds. Then, the number of miles at each speed is multiplied by the emission rate for the corresponding speed, and the results summed across all the speeds indicate the total emissions.

The mesoscopic approach has traditionally been used by transportation agencies and metropolitan planning organizations to analyze the emission impacts of transportation plans, programs, and projects such as widening roads and adding new transit routes. Travel demand models are often used to generate vehicle activity data inputs in terms of vehicle miles traveled or vehicle hours traveled. Vehicle emission rates are usually obtained from the U.S. Environmental Protection Agency's MOVES model, or in the case of California, the California Air Resources Board's EMFAC model. Then, the emission impacts for specific roadways or locations as well as for the entire region can be analyzed.

Microscopic Approach

For analyses of the emission impacts of some transportation projects and technologies, a highly detailed modeling approach that can capture the effects of driving behavior on vehicle emissions is needed. This microscopic approach calculates emissions at high time resolution, typically on a second-by-second basis, as it accounts for the modal operations of vehicles, such as acceleration, deceleration, and idling. For example, carbon dioxide emission rates (per unit time) of cars and trucks are much higher during acceleration than during cruising.

Therefore, traffic flow improvement projects and intelligent transportation system technologies that reduce the number of stops and smooth the traffic flow, such as traffic signal synchronization and ramp metering, can result in reductions of carbon dioxide emissions. Although the microscopic emissions modeling approach provides more accurate emission results than the mesoscopic approach, it is more computationally demanding and requires more extensive data inputs. Thus, it is used more frequently in project-level analyses (such as modeling carbon monoxide and particulate hotspots) than in areawide analyses (for example, regional emissions inventory development).

This modeling approach requires traffic microsimulation tools to produce modal vehicle activity

data inputs in the form of vehicle trajectories (that is, second-by-second position and speed profiles). These vehicle trajectories are used in conjunction with microscopic vehicle emissions models such as MOVES and CMEM to calculate the corresponding emissions. These emission results can then be aggregated for specific roadways or locations as well as for specific time periods in the modeling domain.

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See Also: Environmental Impacts; Microsimulation Models; Mobile Emissions; National Ambient Air Quality Standards; Vehicle Emissions Standards.

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Emissions Trading Schemes

The existence of a relationship between emissions trading schemes and the airline industry is a relatively recent phenomenon. The 2012 incorporation of the aviation sector into the European Union's Emissions Trading Scheme (EU ETS) represented the first time that an application of this market-based instrument has been used in an effort to mitigate airline carbon dioxide (CO₂) emissions. As

such, the knowledge and experience of the relationship between emissions trading schemes and their effects on airlines is limited to what one knows of the European experience in this regard.

Emissions Trading in the European Union

The European Union launched the EU ETS, the world's largest and first transfrontier cap-and-trade scheme, in 2005 as part of its policy response to ensure compliance with its Kyoto Protocol target. In cap-and-trade, annual allowance allocations (tons of CO₂ per annum) are made to participants with the rule that participants hold sufficient allowances at the end of the year to cover their emissions or face the imposition of a financial penalty. (Emissions trading schemes can also take the form of baseline-and-credit, which is not a focus of this article.) Participants are able to sell and buy allowances as they wish, and it is this "trade" element of cap-and-trade that produces an allowance price. This price signal provides an incentive to those for whom abatement is relatively cheap and to sell their surpluses to those for whom abatement is relatively expensive.

Those facing difficulty in keeping their emissions in line with their allocations have a choice between taking measures to reduce their emissions (for example, investing in more efficient technology, using less carbon-intensive energy sources, etc.) or buying allowances on the market, or a combination of the two. Such choices are likely to be determined by relative costs of the different abatement options. In this way, emissions are reduced wherever it is most cost-effective to do so. The existence of an allowance price also provides an economic incentive for technological innovation, as surplus allowances arising from any technological development can be sold. The economic literature typically refers to this innovation aspect of emissions trading as "dynamic efficiency."

Since 2005 a cap has been fixed on CO₂ emissions for the EU's power and heavy-industry sector (refineries, cement, iron and steel, glass, ceramics, paper, and board) during two trading phases (2005–07 and 2008–12). EU ETS coverage accounts for approximately half of the EU's CO₂ emissions and 45 percent of total greenhouse gas emissions. In 2008, the EU in its Climate and Energy Package outlined plans to extend the EU ETS to a third phase from 2013 to 2020. In the same year the EU

adopted legislation that would result in emissions from international aviation (including both EU and non-EU airlines) being included in the EU ETS from 2012.

Aviation in the European Union's Emissions Trading Scheme

The EU decision to include aviation in the EU ETS was driven by two main factors: sectoral emissions growth and international policy inertia. Since the late 1980s the aviation sector has experienced substantial growth, with J. Vespermann and A. Wald (2011) highlighting an annual average sectoral growth rate of approximately 5 percent between 1989 and 2009. The International Civil Aviation Organization (ICAO) anticipates that the 2012–30 period will see carried passenger numbers grow at an annual average of 4.5 percent, reaching 6.3 billion by 2030. Airbus projects a doubling of aircraft fleets over the 2006–26 period. While continual aviation sector growth is welcomed from an economic perspective, such growth poses considerable environmental challenges. By 2020 global international aviation emissions are projected to be approximately 70 percent higher than 2005 even if fuel efficiency improves by 2 percent per year, and it could further grow by up to 700 percent by 2050. Within the EU, direct emissions from aviation account for approximately 3 percent of the EU's total greenhouse gases, with the large majority of these emissions coming from international flights.

The 1997 Kyoto Protocol dictated that international aviation emissions be excluded from the greenhouse gas emissions targets assigned to developed countries and instead entrusted ICAO with the responsibility for developing policies and measures to address the challenge of "limiting" or "reducing" the emissions of this sector. Since the Kyoto Protocol the EU has sought a global agreement developed through ICAO to tackle aviation emissions. However, failure within ICAO thus far to deliver such an agreement or substantive policy and measures compelled the EU to act to address this challenge, culminating in the 2008 decision to include emissions from international aviation in the EU ETS from 2012.

The European Commission's incorporation of the aviation sector into the EU ETS resulted in a CO₂ emissions cap being imposed on all international flights—from or to anywhere in the

world—that arrive or depart from an EU airport from 2012 onward (including flights arriving at or departing from airports in Norway, Iceland, and Lichtenstein; very light aircraft; military, police, customs and rescue flights, flights on state and government business, and training or testing flights are excluded). The EU ETS thus applies to any aircraft operator, whether EU or foreign based, operating international flights on routes to, from, or between EU airports. Such an approach ensures all airlines are treated equally. The European Commission estimates that by 2020 some 183 million tons of CO₂ will be saved per year on the flights covered by the EU ETS. This emissions saving represents a 46 percent reduction compared to “business as usual.”

Emissions Trading Scheme Effects on Airlines

The principal means by which participation in an emissions trading scheme will impact airlines is the financial implications of such participation, with the scale of financial impacts determined by the allowance allocation that airlines receive. In determining the allowance budget for the aviation sector, the European Commission used the 2004 to 2006 period as the baseline for aviation emissions. The commission used this period instead of 1990 because it takes account of the significant growth of the aviation sector since 1990. As the objective of an ETS is to bring about emissions reductions, allowance budgets are typically less than 100 percent of historical emissions, thereby ensuring participants will face an allowance shortage. For 2012 the allowance budget was equivalent to 97 percent of average historical emissions over the 2004 to 2006 period. From 2013 onward, the allowance budget will be reduced to 95 percent of historic emissions.

The allocation of the allowance budget would be facilitated through a combination of benchmarking and auctioning. Eighty-two percent of allowances are allocated to airlines for free via an emissions efficiency performance benchmark. The free allocation of allowances via benchmarking as opposed to grandfathering (allocation based on historical emissions) is seen to reward airlines that undertake early action to reduce their emissions and/or modernize their fleet through investment in more efficient planes with lower emissions output. (Within the EU ETS benchmarks were calculated on the basis of the

number of passengers and freight volume carried and total distance traveled for each airline operator in 2010.) Fifteen percent of the allowance budget is auctioned, and the remaining 3 percent is allocated to a special reserve for later distribution to fast-growing airlines and new entrants into the market.

When details of the commission’s allocation methodology first emerged, the aviation industry expressed concerns that despite receiving 82 percent of their allowances for free, the sector could be faced with significant economic costs (allowance purchase, airline efficiency improvements, fleet upgrades) as a result of inclusion in the ETS. In 2011 the China Air Transportation Association forecast that it would cost the Chinese airline sector 800 million Yuan (\$123 million) in EU ETS compliance costs in 2012 and more than triple that by 2020. For the United Arab Emirates, estimated compliance costs will range between 500 million and 1 billion euros, with Etihad expecting to spend upward of \$394 million between 2012 and 2020.

However, similar to the way the airline industry passes on increases in oil prices and airport charges to passengers in the form of increased ticket prices, passengers can also expect airlines to pass on the cost of their participation in an emissions trading scheme. European Commission (2006) modeling of this issue identified that, assuming airlines fully pass on their EU ETS compliance costs, by 2020 passengers could expect to see an increase in short-haul return ticket prices of between 0.9 and 4.6 euros, with long-haul tickets increasing by 4 to 19.8 euros. European Commission analysis concluded that such price increases would have a negligible effect on projected passenger demand growth up to 2020 due to the demand for airline travel being relatively price inelastic. PointCarbon reported that within the first fortnight of 2012 four U.S. carriers—American Airlines, Delta, United Continental, and US Airways—imposed a \$3 passenger surcharge on their European-bound flights.

Airline Experience With ETS

The EU decision to include both EU and non-EU airlines in the EU ETS was not met with resounding international support. Many non-EU countries (principally the United States, China, India, and Canada) questioned the legality of the EU’s aviation ETS plans, noting that it violates the sovereignty of their states, and threatened significant retaliatory

action. The U.S. airline industry, represented by the American Transport Association (ATA), launched a legal challenge against the EU over its inclusion in the EU ETS. On December 21, 2011, the European Court of Justice confirmed that the EU's aviation ETS legislation does not infringe international law, the principles of territoriality, or the sovereignty of third countries since the scheme is applicable to airline operators only when their aircraft are physically in the territory of one of the member states of the EU. In spite of the court ruling, China in early 2012 banned its airlines from participating in the EU ETS without government approval. In November 2012 President Barack Obama signed into law the European Union Emissions Trading Scheme Prohibition Act of 2011, which prohibits U.S. airline operators from participating in the EU ETS. China also indicated a willingness to consider the imposition of some form of trade restrictions on the EU, such as the delay or cancellation of purchasing new aircraft by its airlines from European manufacturer Airbus.

November 2012 saw non-EU airlines receive a temporary reprieve regarding the EU ETS when the European Commission announced its "stop the clock" policy, which suspended for a year the participation of non-EU airlines in the EU ETS. The Commission's initiative was driven by progress during the November 2012 ICAO Council meeting at which ICAO highlighted the potential for developing a global market-based measure to deal with aviation CO₂. ICAO is currently considering the potential of developing a mandatory offset or a global ETS. Though ICAO discussions are at an early stage, a global ETS would work in a similar fashion to the EU ETS, while an offsetting approach would require airline operators or their parent countries to purchase credits to cover airline CO₂ emissions above a predetermined baseline. In order to give ongoing international aviation talks a better chance of successfully agreeing on a global market measure, the commission agreed to stop the clock on the implementation of the international aspects of its EU ETS aviation until after the ICAO Assembly in September/October 2013. The implication for airlines of this EU policy is that non-EU airlines were not required to surrender allowances to the EU in April 2013 to cover their emissions for 2012. However, airlines operating flights within and between member states would continue to be part of the EU ETS with the associated compliance obligations.

While the EU is optimistic that a global solution can be reached at the upcoming ICAO Assembly, it has reminded all non-EU airlines that failure to reach a satisfactory agreement will see the EU reinstate all EU ETS obligations. The EU ETS aviation legislation is designed such that it can be amended to reflect the implications of a global agreement. Regarding the development of an ICAO market based measures, the EU has highlighted that such a measure must include three key elements:

1. It must deliver aviation emission reductions at least as large as the EU ETS is doing.
2. It must be nondiscriminatory for all airlines.
3. It must contain targets and measures for ICAO member countries.

Conclusion

While airline experience operating within an emissions trading scheme is relatively limited to date, the outcomes from the 2013 ICAO Assembly will go a long way to shaping whether the aviation sector will have to develop a more long-term relationship with emissions trading—within the EU or as part of global scheme—or some other form of market-based measure. As the aviation community looks toward the 2013 Assembly, the focus for those airlines not exempt from EU ETS participation was on the EU's evaluation of 2012 compliance. Data released by the European Commission in 2013 revealed that airlines responsible for 98 percent of the 2012 aviation emissions regulated under the EU ETS had surrendered sufficient allowances to demonstrate compliance. A European Commission official speaking to PointCarbon identified that Chinese and Indian airlines operating commercial flights within Europe were noncompliant with their ETS obligations. With Chinese and Indian airlines continuing to oppose aviation in the EU ETS, in spite of the "stop the clock" policy for non-EU flights, this issue raises the prospect of the EU facing a significant international political battle should ICAO fail to deliver substantive progress on a global aviation agreement and force the EU to once again "start the clock."

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See Also: Air Pollution/Air Quality; Aircraft Engine Emissions; Environmental Impacts; International Air Passenger Transport.

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Employment Location

Urban historians and sociologists have well documented the exodus of affluent, middle-class, and working-class Americans from the inner cities to the suburbs beginning in the 1950s and continuing well into the 1970s. Following the trend, employers and industrial centers gradually transferred jobs to the suburbs, creating an employer, employee, and transportation triangle with paradoxical, policy, and political problems needing to be solved for 21st-century transportation growth and climate health.

People and Jobs Exit the Cities

Statistics from the U.S. Department of Labor reflected employment patterns from 1950 to 1980 following the footsteps of exiting people. In their 1986 article "Suburbs and Satellites: Two Decades of Change" appearing in the *American Sociological Review*, sociologists J. R. Logan and R. M. Golden reported that manufacturing jobs grew 16 percent in the suburbs between 1958 and 1963, but decreased 6 percent in central cities. Between 1963 and 1977, manufacturing jobs dropped by 700,000 in metropolitan areas but grew by 1.1 million jobs in the suburbs.

The same trend proved to be true for retail and wholesale employment, which declined by 100,000 during the same years while the suburbs gained 1.8 million jobs. While this combination of migration-stimulated job decentralization and employment located in the suburbs encouraged people to live in the suburbs, the trend slowed after the 1970s and 1980s.

As the suburbs grew, so did the use of automobiles and so did commuting problems. Long, tiring commutes on congested freeways reduced job productivity, yet centralized employment districts located in cities benefited employers sharing ideas, workers, and clients. Proximity to other businesses, especially related industries, was an important competitive factor for businesses, and the best climate for these conditions occurred when jobs and businesses were concentrated into centers.

Decentralization and Inner City Poverty

Harvard economist John Kain first advanced the spatial mismatch thesis in a 1968 article in the *Quarterly Journal of Economics*. He studied the locations of homes of African Americans in Detroit and

Chicago and trends in the locations of employment opportunities in both cities, and he discovered that while businesses were decentralizing at a rapid pace, housing discrimination, poverty, and inadequate public transportation connections prevented African Americans from following jobs to the suburbs. Subsequent studies including a 1998 study by Keith Ihlanfeldt and David Sjoquist of Georgia State University reinforced Kain's findings and suggested that the 1960s patterns became more entrenched as low-income and minority populations remained concentrated in central city locations while businesses continued to decentralize rapidly. In the 1990s, welfare reform initiatives catapulted access to jobs into a central public policy question in states and metropolitan regions across the United States and caused public officials to reexamine transportation links between welfare recipients and job locations.

In 2000, complying with President Bill Clinton's 1994 executive order on environmental justice, the Federal Highway Administration required metropolitan planning organizations (MPOs) to demonstrate that regional transportation plans addressed the transportation needs of low-income and minority populations. More recently, geographic information systems (GIS) technology improved the analytical capabilities of spatial mismatch research by giving researchers the tools to pinpoint percentages of low-income households within walking distance of public transit in a region and the percentage of job opportunities located within walking distance of public transportation.

From Suburbs to City

During the 2000s, the city-suburbs job decentralization issue in America reached an unexpected tipping point. A 2013 Brookings Institution book by Elizabeth Kneebone and Alan Berube, *Confronting Suburban Poverty in America*, reported that between 2000 and 2011, the number of suburban poor people in the United States grew by 64 percent, doubling the rate in the cities and proving that more poor people live in the suburbs than in the inner cities.

The book suggested that many suburbs do not have public transit networks connecting impoverished neighborhoods to job opportunities and people tend to be scattered over larger areas in the suburbs. Suburbs usually do not have the built-in service provider networks that inner-city communities have established over the decades. The authors emphasized

that the overall picture is a mixed one when they said that some poor people living in the suburbs enjoy the benefits of better housing, safer neighborhoods, and higher achieving schools than in cities. They noted that others face "lengthy, costly commutes to work, a lack of reliable transportation, and an absence of basic health and social services that are often more fully available and established in cities."

The Northern California Megaregion Pattern

Northern California contains nearly 60 Fortune 1000 companies, with only one-third of them based in the megaregion's central cities of San Francisco, San Jose, Sacramento, and Oakland. California State Senate Bill 375 calls for transportation planning that reduces driving and specifically discusses housing planning measures that are equally important for employment. Sprawling patterns of job location heighten the need for vehicles and highways and discourage regional public transit.

This pattern repeats itself in megaregions across the country, a pattern of sprawling job growth that challenges 21st-century development. As the boundaries of megaregions expand outward, they produce unsustainable commute patterns, car-oriented suburbs, and increased greenhouse gas emission levels. Regional planning and employment patterns need to change if the United States and the rest of the world are to meet the challenges of climate change.

Slowing the continued outward growth of jobs from developed employment centers and shifting commuters into sustainable commute modes will take coordinated planning at political, corporate, and individual levels. A few beneficial planning measures include shifting more work back into traditional transit-served downtowns, concentrating more employment at suburban transit stations, remaking existing low-density office parks into higher density employment districts that could be served by transit, reforming self-enclosed car-oriented companies, and increasing telecommuting and distance learning.

A vision recognizing the multicenteredness of a megaregion but reshaping the geography for a 21st century with increasing nondriving alternatives is an essential part of a plan to combat climate change and ensure economic growth.

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See Also: Climate Change, Transportation Adaption to; Energy Costs; Environmental Impacts; Executive Order 12898; Health Issues; Jobs–Housing Balance/Spatial Mismatch; Urban Sprawl Versus Compact Development.

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transportation. Energy costs therefore affect consumer choices during the selection of mode of transport and even whether to travel at all.

Transportation is a key activity to economic growth. The cost of transportation has overall declined—largely as a result of technological improvement. Vehicles have become more efficient. Furthermore, improvements in manufacturing have resulted in improvements in durability and longevity, resulting in a decreased need for maintenance and improvement. However, with finite resources available, the cost of energy to power transport is set to rise in the long term. Furthermore, many believe that the “external costs” of using dirty sources of energy should be factored into the price consumers pay for energy through eco-taxes or carbon pricing. This has the potential to change the economics of transportation in the future.

Oil Supply and Demand

At present, the U.S. transportation system is primarily reliant on oil as the principal source of energy for automotive, marine, and aviation applications. With any extractive resource, there is a balance between supply and demand and the cost that can be charged for a unit of fuel used to deliver primary energy.

Fossil fuels are in finite supply. The oil geologist Marion King Hubbert made a prediction that has come to be known as “Hubbert’s peak” or “peak oil.” This prediction follows that extraction and consumption of any natural resource will follow a “bell-shaped curve.” Here, the y axis represents oil extraction, while the x axis represents time passing. At the top of the curve, the condition of “peak oil” is said to have been reached. This is the point at which extraction reaches its highest rate. After that point, it becomes increasingly hard to locate and realize new oil reserves. Once peak oil has been crossed, extraction of that finite resource can only enter a period of decline and scarcity. Understanding this graph is crucial to realizing that the price of fossil fuels can only ever escalate in the period of time leading up to peak oil and will rise sharply in the immediate aftermath.

There is some uncertainty globally about the point at which peak oil will be reached, as it is hard to know how much oil is ultimately recoverable globally. It is, however, known that the United States reached its peak of oil production during

Energy Costs

All modes of transportation require energy in one form or another to move goods and services from one place to another. Energy costs form one of the most significant components of the overall cost of

the 1970s. As oil that is easy to extract becomes in ever constrained supply, attention has turned to nonconventional oil sources—such as those that can be obtained from tar sands. These reserves come with vastly increased external costs to the environment. Nonconventional oil resources are highly carbon intensive to utilize. Being of poorer quality, they require additional energy to extract and refine into usable petroleum products. There is also concern that the extraction of nonconventional oil resources causes massive environmental degradation.

Oil supply—and hence price—is controlled by producers internationally. In this respect, one of the largest supplier blocs is OPEC, the Organization of Petroleum Exporting Countries. This is a cartel of oil-producing countries that work together to maintain the price of oil in the short term, while also ensuring a steady supply to consumers.

There is a global geopolitical dimension that can affect energy prices. Instability in countries that produce oil can lead to oil prices escalating, as the market attempts to compensate for perceived potential challenges with supply.

One of the determinants of oil demand globally is the level of economic activity. When global economies and markets are strong, there is high demand for fossil fuels to power the economy. As economic activity declines, so there is less demand for fossil fuels.

1973 Oil Crisis

In the early 1970s, the United States had passed its peak of oil production. James Akins was asked by President Richard Nixon to audit the U.S. oil production capacity and found, alarmingly, that there was no spare capacity. That year, there were tensions in the Middle East and a conflict began to escalate between Egypt and Syria, with other Arab nations, and Israel. Because of the U.S. support for Israel, the OPEC countries decided to raise the price of their crude oil output dramatically. This had manifold implications for Western economies. This sudden change in energy prices shaped Western attitudes to oil exploration and discovery and energy-efficiency measures. For a brief period there was resurgent interest in alternative technologies to oil for transport applications and a brief period in which manufacturers brought smaller and more economical vehicles to the marketplace.

While prices eventually stabilized, the effects of the oil shock were lasting in that it alerted governments to the impact of rising energy prices on transportation activities and the economy.

Energy Costs in Transportation

The costs of energy have to be situated in a wider landscape of transportation costs. They are just one factor that affects the economies of transportation. That said, it is a given that primary energy costs will rise in the long term.

Running private cars is much less economical than public transport vehicles. As private cars often spend a significant proportion of their life span unused and idle, they have poor capacity utilization. As a result, for private vehicles, factors such as depreciation have a bigger impact on the cost per passenger mile traveled. Energy costs are just one of the plethora of costs vehicle owners face—there is also the cost of repair and maintenance, insuring the vehicle, taxes and registration fees, and costs for using the vehicle, such as tolls and parking charges.

For commercial vehicles with high rates of utilization, energy factors figure more heavily. In the road haulage industry and shipping and aviation, energy costs are a more significant element of the cost per vehicle mile traveled. Furthermore, at present, some areas, such as shipping and aviation, are largely exempt from taxes on the fuels they consume as a result of international agreements. There is pressure to recognize the “external” environmental costs of using dirty energy sources. Additional taxes levied on fuel could in the future add to the energy costs of these transportation industries.

While the cost of energy has risen, to some degree this has been offset by improvements in engine design leading to more efficient engines and improvements in manufacturing resulting in cheaper, more durable vehicles; this has meant that while the cost of energy has risen, the cost of transportation has in real terms fallen.

There are, however, technological limits to how much improvements in existing gasoline engine efficiency will be able to improve to balance out the escalating costs of primary energy. As energy prices escalate and efficiency improvements diminish, there will be a point at which energy costs become more dominant in the transport economics equation.

Fuel Tax

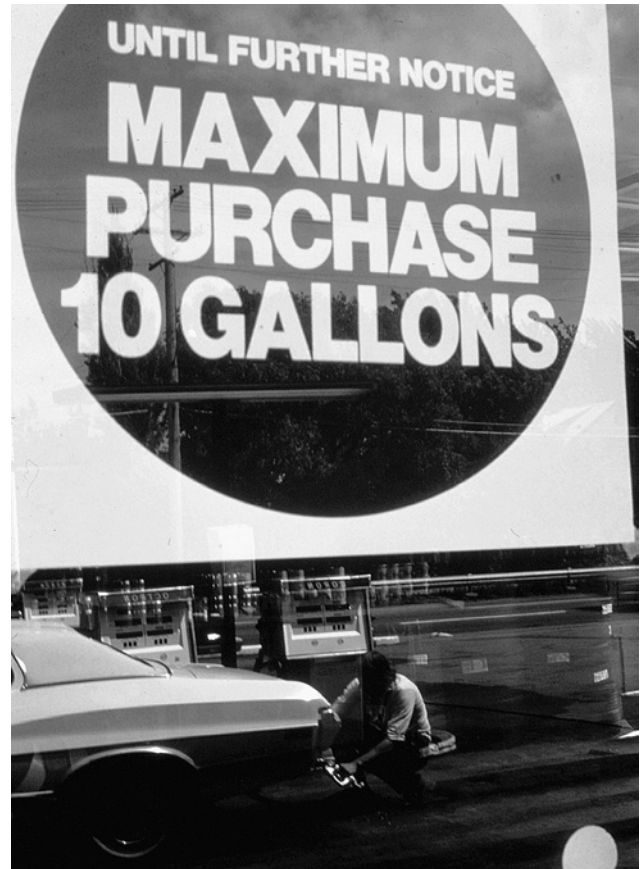
Fuel tax, also known as fuel duties and fuel excise, is a tax applied by the government to oil products. Often, the rate of tax applied to fuels used for road transport differs from the rate levied on fuels used for agricultural purposes or for home heating. Fuel tax systems can be designed as ecological taxes, to promote the use of alternatives to fossil fuel. Here, biofuels, which provide the same function—albeit from a natural source—may be taxed at a lower rate than fossil fuels to incentivize their use. Fuel taxes are implemented at different rates around the world according to country. European countries tend to impose high fuel taxes, while the United States, Canada, and Australia tend to have low fuel taxes.

In some countries where fuel used for agricultural or home heating purposes attracts a different rate of tax, the fuel can be “dyed” using a colorful hydrocarbon dye. This helps prevent tax avoidance by staining not only the fuel, but the tank of the vehicle the fuel is used in. Should dyed fuel attracting a lower tax rate be used in a road vehicle, the infringement can easily be detected by “dipping” the tank. In order to try to circumvent this duty, criminal organizations have been known to carry out a process called “fuel laundering” in which cheap, agricultural fuel is stripped of its color through a chemical process, producing “clear” or white diesel, identical to road diesel. In addition to evading excise, there are also consumer concerns that this illegal fuel can be of an inferior quality and damage vehicles.

While fuel for motor vehicles is generally taxed, fuel for marine purposes has largely been exempt from taxation. Internationally, there are a large number of bilateral service agreements in place between various countries.

Aviation is another area that benefits from lower taxes on fuels. For international commercial aviation, there are often bilateral service agreements in place between countries, resulting in tax exemption for fuel used for international commercial flights. Often there are different tax regimes in place for domestic flights. Furthermore, fuel for general aviation may be taxed differently than commercial aviation.

As of 2013, existing international climate agreements have focused on the regulation of emissions from land-based activities. There is international consensus in the scientific community that drastic reductions in carbon emissions will be needed to halt the prospect of irreversible anthropogenic



A sign in the window of a U.S. gas station limits fuel purchases during the height of the oil crisis in 1973. The crisis began when OPEC countries raised the price of their crude oil output, leading to a spike in gasoline prices of nearly 400 percent between October 1, 1973, and January 1, 1974.

(man-made) climate change. Politically, it has been more challenging to achieve a consensus on what action is required to reduce carbon emissions globally.

Bunker fuel, heavy fuel used for shipping, accounts for around 5 percent of global carbon emissions. It also is used to facilitate around 80 percent of global trade. Therefore, the market is sensitive to the cost of bunker fuel. There is a direct relationship between fuel taxes and vehicle usage. Where fuel taxes are raised, they modify consumer behavior. In the short term, these are changes in consumption behavior—with drivers choosing to drive less. Where fuel taxes are held high in the longer term, they can affect vehicle purchasing decisions. High fuel taxes over time may result in drivers choosing smaller, more fuel-efficient vehicles.

Many have said that carbon taxes on shipping and aviation look to be a likely climate mitigation measure for the future. This could lead to reductions in use of air transport and shipping services. This is likely to have far-reaching social consequences and may change patterns of trade and transport, depending on the levels of future eco taxes.

Fuel Price Risk Management

There is now an increasing array of sophisticated financial instruments designed to help provide certainty for companies that are working in the transportation business. Given that energy costs are such a significant component of the operating costs of any transport business, companies need a degree of certainty so that they can offer stable prices to customers—while the business is not exposed to any undue degree of risk. The financial instrument used to help stabilize fuel prices is known as a “hedge.” A hedge is a way of investing to offset any potential future losses or gains. By using financial instruments such as commodity swaps and options, heavy consumers of fuel are able to establish capped or fixed fuel prices—which assists with business planning, forecasting, and accounting.

Comparing Fuel Options

It is challenging to make comparisons between the economics of different fuel types in vehicles. One measure that can be used is miles per gallon gasoline equivalent, expressed as MPGe or MPGge. The metric equivalent of this would be “kilometers per liter equivalent.” Here, vehicles using alternative energy sources are compared with the measure of efficiency commonly applied to fossil fuel vehicles—“miles per gallon.” In the United States, where this measure is applied by the Environmental Protection Agency, an equivalence figure of 33.7 kWh per gallon is used to express the energy content of petrol/gasoline to enable comparisons to be made between electric and conventional vehicles. Through this measure, and knowledge of the costs per gallon of fuel and kWh of electricity, it is possible to make accurate cost comparisons when evaluating the energy costs of a range of different vehicles.

New Transportation Energy Sources

There is a need to transition away from fossil fuels to newer transport energy technologies. Presently, electricity is used to power some railway lines and

other transport infrastructures with fixed routes, such as urban trams and trolleybuses. Here the electricity is conveyed to the vehicle by rail or overhead catenary wire. The electricity to supply these applications will come from a variety of primary energy sources, depending on the location and the mix of technologies producing grid energy. Electric motors are very efficient across a range of speeds. If the power is coming from nonrenewable sources, then fuel will be burned in a thermal power station. There are losses in generation and distribution of the electricity—but even considering these, the efficiency of the electric motor means that the cost of energy for running these vehicles is still lower than their fossil fuel counterparts. Here, in economic terms, the cost of the energy required to run alternative fuel vehicles is often much lower than fossil fuel vehicles. However, the challenge is that the capital cost of investing in the initial technology and/or infrastructure required to support the technology may be high and affect the overall economics of the transport solution.

Making electric vehicles that are not tied to fixed infrastructure is more challenging. There are additional losses involved in storing energy and transporting the weight of batteries.

Some low-speed, low-range applications can use very simple battery chemistries, such as the commonplace lead-acid battery, which is comparatively cheap. In some transport applications, this simple electric vehicle technology is appropriate. For higher performance transport applications, more sophisticated battery chemistries are required. This adds significantly to the purchase cost of the vehicle. The high cost of batteries for energy storage adds significantly to the vehicle purchase price and may also require periodic replacement as batteries degrade. This is offset by savings in the energy costs over the vehicle’s lifetime.

Another potential avenue for providing energy to vehicles is in the form of hydrogen and fuel cells. Hydrogen generates only water at the point where it reacts with oxygen in the air. Again, this is an early-stage technology. The cheapest way to produce hydrogen is steam reformation. This process is presently used internationally to produce hydrogen commercially. This does, however, come with the disadvantage that as a by-product of the process, methane used as a feedstock is converted into hydrogen but the carbon from the process ends up

as carbon dioxide. So while this is the cheapest way to produce hydrogen, and no carbon emissions are produced at the point of use, there are still carbon emissions resulting from the process.

One possible alternative is to produce hydrogen from electrolysis of water. This would be a much more expensive process. There is the potential, however, to use “off peak” electricity in the middle of the night or at times of low demand to produce this hydrogen. This could help make use of “surplus” energy and keep the costs of producing hydrogen down.

To incentivize the use of electric vehicles, many municipalities and businesses are providing free electric charging stations. As the energy for powering electric vehicles is so cheap, the benefits accruing to a business—through retention of customers, more time spent in store browsing, etc.—more than offset the cheap cost of the energy supplied free.

As alternative vehicles are in the very earliest stages of development and market penetration, the mechanisms used to price the energy they consume are not well developed. There are many interesting debates, for example, might energy used for powering electric vehicles be charged at a different rate from domestic energy? Furthermore, through demand-side management measures, there is the potential for electric vehicles to act as a useful tool for balancing the variable energy output of renewable sources—in future energy scenarios where a much greater proportion of grid energy comes from these sources.

One solution that has been considered for a future transport energy scenario is the idea of “smart grids.” Here, in addition to electricity being supplied by the grid, there is also information about the availability of energy from the grid. Pricing is potentially dynamic, creating a market of supply and demand. When there is an abundance of renewable energy and insufficient demand, the price of the grid electricity drops. Devices interacting with the grid could be programmed to only use cheap electricity below a certain tariff. Thus, if there is suddenly a spike in demand, or a drop in supply, devices programmed to only buy off peak electricity will disconnect from the grid. For an application like charging an electric vehicle, this will have no noticeable impact to the customer (for example, if he/she is charging a car overnight) but manifold benefits for the grid and cost of providing energy.

At the moment, as governments around the world seek to encourage alternative vehicles, the energy that powers them is often taxed at rates that incentivize use. However, as market penetration is achieved and alternative fuel vehicles become commonplace, it is inevitable that taxation regimes will change and these will be reflected in the energy costs of powering these vehicles.

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See Also: Alternative Fuels; Automobile Industry, Economics of; Automobile Operating Costs; Benefit–Cost Analysis of Transportation; Green Fuels; Transit Industry, Economics of; Transportation, Economics of.

Further Readings

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Energy Policy Act of 1992

The Energy Policy Act of 1992 (EPA 1992) represents one of the most significant pieces of legislation in the area of energy policy and law in the United States. It promotes energy efficiency and the use of renewable energy. It is organized in 27 titles addressing various elements of energy policy

and law relating to, among other things, energy efficiency in buildings and industrial sites, natural gas, high-level radioactive waste, and coal policies. The overall goals of the act relate to the ambitions to reduce the reliance on costly oil imports; conserve and more effectively use available energy; reduce the use of traditional, petroleum-based fuels in motor vehicles; increase competition in alternative fuels markets; address global warming; implement solutions relating to nuclear waste; and secure sufficient oil reserves.

Definition and Designation of Alternative Fuels.

The EpAct 1992 provides a nonexhaustive list of substances that can fall under the definition of alternative fuels in section 301(2). On one hand, these can be alcohols, such as methanol or denatured ethanol or mixtures of alcohols with gasoline, natural gas, hydrogen, coal-derived liquid fuels, liquefied petroleum, and other fuels. The proportion of alcohols should be at 85 percent or more and, in certain circumstances, determined by the secretary of energy's rule, can be at 70 percent or more. On the other hand, the definition contains a degree of flexibility as it can include, when determined by rule by the secretary, any other fuel that is "substantially not petroleum and would yield energy security benefits and substantial environmental benefits" (the three criteria).

The inclusion of the additional fuels to the pool of alternative fuels is made possible through sending a petition to the U.S. Department of Energy (DOE). The DOE has considerable discretion to determine whether the proposed fuel will be classified as an alternative fuel on the basis of the application. The discretion stems from the fact that the decision-making process is highly resource intensive. The applicant must prove that the fuel meets the three criteria with extensive high-quality data. Further, the supporting material sent by the petitioner is published online and made available to the general public.

As of 2013, the DOE was still in the process of considering Rentech, Inc.'s petition to designate diesel fuel made from natural gas using the Fischer-Tropsch process. The petition was submitted in July 1999, thus providing an example of how complicated and time consuming the process of designation under s. 301(2) of the EpAct 1992 can be.

Covered Fleets

The act imposes certain requirements on the "covered fleets" that are addressed to state entities and alternative fuel providers' fleets. State entities, including state universities and colleges, can report as a single entity or on an agency basis. The alternative fuel providers should engage principally in producing, storing, refining, processing, distributing, transporting, and importing or selling alternative fuels. The definition also includes those producing, transmitting, importing, or selling electricity and those who produce or import petroleum with significant revenue generated from producing alternative fuels. First, it is important to ascertain whether a given fleet is a "covered fleet"; second, ensure that the operators or controllers of the covered fleets meet the requirements specified in the act. The paragraphs immediately below provide an explanation relating to the first question, followed by a description of specific requirements that must be met by covered persons operating the covered fleets.

Both state entities and alternative fuel provider fleets are subject to the same test consisting of three elements. First, they should own, operate, control, or lease at least 50 motor vehicles within the United States. Under section 301(9) EpAct, certain vehicles are excluded from the count, for example, law enforcement vehicles; emergency vehicles; vehicles used for product evaluations, tests, or demonstrations; nonroad vehicles, including farm and construction vehicles; and vehicles kept for lease or rental to the general public. Second, 20 out of at least 50 qualified vehicles must be used primarily within a single metropolitan area or a consolidated metropolitan statistical area with a population of 250,000 as of 1980. Third, the same 20 motor vehicles must be centrally fueled or "capable of being centrally fueled." The DOE sheds more light on the capability issue by stating the following:

. . . [v]ehicles are considered capable of being centrally fueled if they are capable of being fueled at least 75 percent of the time at a location that is owned, operated, or controlled by any fleet or under contract with that fleet for fueling purposes.

As of May 3, 2012, there were 296 covered fleets listed by the DOE. These included state entities

such as Arizona State, specific agencies such as the Texas Department of State Health Services, universities such as Pennsylvania State University, and private alternative fuels, electricity, and petroleum companies.

State Agencies: Acquisition Requirements.

State agencies may take possession of new motor vehicles, including used vehicles, from time to time. When the state fleets are covered by the act, the operators must ensure that 75 percent of newly acquired low-duty vehicles must be alternative fuel vehicles (AFVs). The calculation is fairly straightforward: if a state entity decides to acquire 205 vehicles in a given year and five of them are excluded vehicles (for example, nonroad cars) then 150 newly acquired vehicles must be AFVs. On occasion, the state entities may not be able to meet the acquisition requirements. They can apply to the DOE for an exemption, supported with evidence, after exhausting all possible avenues to satisfy the requirements. The DOE may grant such an exemption, which will only apply to a given model year and will not be renewable. The state entities may also apply for an exemption based on the unavailability of appropriate alternative fuels for their AFVs or on the basis of financial hardship. In all circumstances the DOE will consider such applications on a case-by-case basis. The acquisition requirement is accompanied with a reporting duty. Each operator of the covered fleet must submit an annual report using predetermined forms on the status of compliance to the DOE. The operators enjoy considerable discretion whether to submit one report as a single state entity or separate reports by each agency in the state.

**Alternative Fuel Providers:
Acquisition Requirements**

Similar requirements apply to the alternative fuel providers' covered fleets, albeit with certain differences. Thus, the threshold is significantly higher and such operators must ensure that 90 percent of newly acquired low-duty vehicles must be AFVs. The operators may choose to comply with the acquisition requirements as a single entity, including associated entities and subsidiaries, or as a number of separate entities. There is also some flexibility for the companies that merge or split in a given year of compliance with the acquisition requirements. In such circumstances, the companies may choose

to comply and report as a single entity or as a set of individual entities. As with the state entities, the businesses may apply for an exemption, supported with evidence, to the DOE in a given year. If granted, the exemption is valid for one year only.

Alternative Fuel Vehicle Credit Program

Overall, the compliance with the act is on an annual basis, which is reflected in the reporting requirement. However, the operators are allowed to take account of the longer time horizons in a form of an AFV credit program. The purpose of this scheme is to inject some flexibility without undermining the overall goals of the act to minimize the dependence on traditional fuels. Thus, the covered fleets earn credits when exceeding the statutorily required number of acquisitions of AFVs in a given year or acquiring the vehicles earlier. One vehicle is worth one credit, and DOE keeps a credit account for each covered fleet and presents them with an annual credit statement. The credit program functions similarly to other trading schemes. Thus, the entities can exchange, sell, buy, or give away the credits in the present and in the future. The traders should complete a transaction form and send it to the DOE within 30 days of the transfer date.

**Executive Order 13149:
Alternative Fuel Vehicles**

It became clear that the Energy Policy Act of 1992 was significantly flawed because it focused on the acquisition of AFVs and not on the use of alternative fuels. To reconcile this problem, in April 2000 President Bill Clinton issued Executive Order 13149 addressed to federal agencies. Section 201 of the order states the following:

. . . each agency operating 20 or more motor vehicles within the United States shall reduce its entire vehicle fleet's annual petroleum consumption by at least 20 percent by the end of [financial year] 2005, compared with [financial year] 1999 petroleum consumption levels.

The agencies should prove compliance with the requirement through a development of performance strategies. They can adopt measures suggested in the order such as the use of alternative fuels heavy-duty vehicles alongside the low-duty vehicles, a reduction in overall mileage. The agencies

can also develop their unique performance strategies with innovative measures and goals to meet their particular needs. All agencies should increase the average fuel efficiency of their cars and ensure that alternative fuels are used for the majority of the fuel requirements of the alternative fuel vehicles. In this sense the order complements the requirements entrenched into the EAct 1992.

Alternative Method of Compliance

The Energy Policy Act of 2005 (EAct 2005) provided for an additional alternative method of compliance with the acquisition requirements under EAct 1992. Thus, the alternative compliance allows the covered state entities to apply for waivers from the standard compliance acquisition requirements. Instead of focusing on the acquisition of alternative fuel vehicles, the entities that were granted the waiver focus on the reduction in the use of petroleum-based fuels. The participation is based on an annual basis. The entities interested in participating in the alternative compliance in a given year must submit an application to the DOE. The application should contain information demonstrating how the organization plans to achieve a reduction in the use of petroleum that will be equal to the predicted use of the alternative fuels during that year. To calculate the balance, the entity should take account of the existing fleet of AFVs and the AFVs that the organization would have to acquire during the application year. The application should contain reliable data, all of which will be verified by the DOE before granting the waiver.

Apart from the general flexibility, the alternative method can address certain problems that the entities may face in satisfying the standard compliance with EAct 1992. Some entities may have to apply for exemptions if the alternative fuels are not available in their area. The alternative compliance method allows those entities to use the waiver in lieu of the exemptions, which are granted on a case-by-case basis and thus unpredictable. Further, the entities may also calculate the reductions in the use of traditional fuels by taking into account the results achieved by the heavy-duty vehicles. In certain circumstances the applicant may also include the nonroad vehicles into the overall calculation. The DOE issues a decision whether to grant the waiver within 45 days from obtaining all necessary and verifiable information in the application. If

the decision is positive, the entity should carefully implement the reduction plan by keeping records of all measures. Such entities must also submit annual reports to the DOE demonstrating compliance with the reduction plan.

Provision of Information

The EAct required the secretary of energy, in consultation with the relevant federal agencies and experts, to establish a public information program. The intent of the scheme is to familiarize the general public and the fleet operators with the costs and benefits of using alternative fuels and AFVs. The government should provide verifiable and accurate data that can assist the public in choosing the appropriate fuels. The relevant information can also be provided through the effective labeling. At present, the DOE maintains a number of Web sites consisting of much information on alternative fuels. It also runs workshops and designs, codesigns, or supports a number of programs such as Clean Cities, State Energy Program funding, National Clean Diesel Campaign, Clean School Bus USA, Clean Ports USA, and Clean Construction USA. In terms of labeling, the AFVs and fuel dispensers must contain labels providing appropriate information to allow consumers to make an informed decision about the purchase. Thus, for example, the labels attached to the fuel dispensers must specify the name of the fuel and the fuel rating.

Compliance Data

In 2000, less than half (seven) of 18 covered federal entities met the 75 percent acquisition requirement. It was reported that nine agencies increased their reliance on traditional petroleum fuels between 1999 and 2000. Two years later nine agencies failed to satisfy the 75 percent requirement; the figure dropped to five in 2003. In 2007 the entities had a first opportunity to apply for the alternative method of compliance. In that year the overall compliance with the standard method was reported at 97 percent. In 2011 (reported in 2012) all 293 covered entities complied with either with the standard or the alternative methods. Two hundred eighty fleets chose to work with the standard method and 63 percent of them exceeded their 2011 acquisition requirements. The covered fleets that chose to work with the alternative method exceeded their reduction targets by 80 percent.

EPA 1992 and Clean Cities

The above-described mandatory requirements have been amended and developed over time to embed flexibility into the acquisition schemes. Flexibility is required because, with rapidly advancing technology and economic cycles, the command and control regulation proves largely ineffective. Yet, section 505 of the EPA 1992 consisted of a provision titled “Voluntary Supply Commitments.” The government was originally required to identify voluntary commitments in geographically diverse parts of the United States.

The scheme aimed at linking fuel suppliers, owners of 10 or more vehicles, and suppliers of alternative fuels. Thus fuel suppliers could “make available to the public replacement fuels” and provide for “the construction or availability of related fuel delivery systems”; owners of the vehicles could be encouraged to acquire AFVs and alternative fuels; whereas the suppliers of AFVs could “make available to the public alternative fuelled vehicles and to ensure the availability of necessary related services.” Section 505 provided a foundation for the Clean Cities Program, which has expanded significantly since its establishment in 1993.

As of 2006 there were about 90 coalitions that brought together approximately 4,400 stakeholders. The coalitions covered a population of nearly 180 million citizens, that is, about two-thirds of the overall U.S. population. Since then the scheme has grown significantly. As of 2013 there were nearly 100 Clean Cities coalitions across the United States bringing together about 13,000 stakeholders from public and private sectors. Today, the coalitions include about 228 million people, which is approximately 74 percent of the overall U.S. population.

The stakeholders include the aforementioned owners and suppliers and, in addition, local governments, national laboratories, state and federal agencies, and other organizations. The coalitions stimulate collaboration and exchange of information creating opportunities for networking and dissemination of technical information. They also facilitate adoption of new technologies in the regions. The regional coalitions are complemented with and supported by the national partnerships, including National Clean Fleets Partnership, National Parks Initiative, Electric Vehicle Infrastructure Training Program, and Advanced Vehicle Technology Competitions.

There are ongoing possibilities for establishing further coalitions. The prospective applicants should have an active network of stakeholders, a clear organizational structure and goals, an identified coordinator, and funding. The DOE Web site provides up-to-date information as to available funding programs.

Electric Motor Vehicles

Title VI included a number of provisions aimed at promotion of and encouragement to use electric motor vehicles (EMVs). These provisions have been complemented with and extended by other statutory and nonstatutory initiatives. The sections below concentrate on explaining the original provisions.

Under Subsection A the government was required to establish an EMV demonstration program with an allocated funding of up to \$50 million. The primary goal of the scheme was to foster the development of electric vehicles and evaluate the performance of such vehicles. The secretary of energy was required to “solicit proposals to demonstrate electric motor vehicles and associated equipment” in metropolitan areas. The prospective proposers of the demonstrations had to provide certain information in their applications, such as description of the vehicles, the suggested users of the electric vehicles, the number of vehicles to be demonstrated, and their life cycle costs. The chosen proposers could demonstrate and sell their vehicles in specified areas. Crucially, the proposers could offer a discount to the buyers or leasers and the government would provide the proposer with a reimbursement. The maximum reimbursement was established at \$10,000. In return for the discount, the users of the electric vehicles agreed to provide the government and the proposers with information regarding the operation and performance of the vehicles.

Subtitle B of Title VI allocated up to \$40 million for the development of infrastructure and supporting systems for electric motor vehicles. Under section 622 the secretary was required to solicit proposals from persons willing to engage in cost-shared research; development, proportion, and application of an infrastructure; and support systems programs. The projects could include the following: servicing electric vehicles, installation of charging facilities, development of health and safety measures, guidelines concerning battery charging and emissions,

information exchange programs, and other initiatives deemed necessary by the government.

Revenue Provisions

Tax provisions play an important role in encouraging the use of alternative vehicles as opposed to traditional fuels in transportation. In the 1980s the U.S. government under the Ronald Reagan administration was not in favor of using tax law to promote a greener economy. It was believed that a free market approach and especially high oil prices would encourage the public to use the alternatives. The approach was not fully successful as, at the end of the decade, oil prices were very low. The Energy Policy Act 1992 was a major legal instrument that marked a move away from the free market approach toward a more interventionist course in relation to tax provisions.

Fringe Benefits for Employers

Section 1911 regulated so called qualified transportation fringe, that is, means of work-related transportation and parking facilities that were encouraged through tax exemptions. The qualified transportation fringe included (1) "transportation in a commuter highway vehicle" between the place of work and the employee's residence; the vehicle should have at least six spaces for passengers; (2) "any transit pass" that entitles an employee to use private or public mass transportation or a commuter highway vehicle; and (3) qualified parking near the place of work or near the location from which the employee catches the qualified vehicle to commute to work. The qualified parking explicitly excluded parking spaces on or near the residence of the employee. It is important to note that the EAct 1992 expanded the meaning of "transportation fringe" as prior to 1992 only qualified parkings were regulated as fringe benefits.

The employer could provide benefits exempt from tax to the employee for the purpose of using the above means of transportation and parking. The amount of benefits was capped at \$60 per month for the use of commuter highway vehicles and transit passes, and \$155 per month for the use of the qualified parking.

Deductions

Section 1913 provided a range of incentives for the individual or business taxpayers in relation to the

purchase of clean fuel vehicles and electric vehicles and for the installation of refueling properties. Taxpayers could benefit from deductions of between \$2,000 and \$50,000 in the year in which they put a clean vehicle into service and \$4,000 for purchasing an electric vehicle. They could benefit up to \$100,000 for placing a refueling property into service during a taxable year.

Conclusion

The Energy Policy Act of 1992 was an important and complex piece of legislation that dealt with, among other things, energy issues relating to transportation. This article has described the core provisions whose aim was to encourage the use of alternative fuel vehicles, electric vehicles, and the installation of the appropriate support facilities such as refueling stations. Some of the provisions were mandatory and others voluntary, resulting in a formulation of mutually reinforcing pillars. Many of the provisions have been amended by subsequent legislation such as the Energy Policy Act of 2005; thus, the reader is urged to analyze the EAct 1992 in the context of later legal and policy mechanisms.

How successful have the EAct 1992 provisions in encouraging the use of cleaner energy in transportation? A 2010 report prepared for Congress by the Department of Energy is somewhat cautious in pronouncing a big success:

Overall, the EACT programs displace hundreds of millions of gallons of petroleum annually. This amount, however, is less than one percent of the approximately 175 billion gallons of petroleum used on the nation's highways each year.

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See Also: Air Pollution, Automobile; Alternative Automotive Fuels; Electric Vehicles; Energy Costs; Environmental Protection Agency; Ethanol.

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Energy Policy and Conservation Act of 1975

On December 22, 1976, President Gerald Ford signed the Energy Policy and Conservation Act (EPCA) into law (P.L. 94-163). The act (S. 622) was the culmination of a year-long struggle between the executive and legislative branches to develop what the president called "the basic framework of a national energy policy." The debate over that policy had been ongoing for several years in response to concerns over America's dependence on foreign oil and the damage that fossil-burning fuels were exacting on the environment. Support for developing alternative sources of energy continued to rise during and after passage of the EPCA, and the act was eventually amended to focus on that aspect of energy policy. Upon signing the bill, Ford bemoaned the fact that U.S. dependence on foreign oil had continued at "an intolerable rate" following the oil embargo of 1973. The most far-reaching aspects of the EPCA may have been the creation of Corporate Average Fuel Economy (CAFE) standards, which mandated the manufacture of more fuel-efficient cars and light trucks, the expansion of

U.S. oil reserves, and empowering the president to deal with oil crises.

While unhappy with the final version of the bill, the president recognized that establishing a framework for energy policy was more important than continuing to engage in political squabbles. Ford cited three major reasons for signing the bill. First of all, the EPCA allowed him to continue working toward meeting his midterm goals for energy independence as laid out in his first State of the Union address. It accomplish this action through creating a strategic storage system, mandating the conversion of oil- and gas-fired plants to those that burned coal, implementing energy efficiency labeling, establishing emergency authority for dealing with any future oil crises, and empowering the government to fulfill agreements with other oil-consuming nations.

The second reason that Ford agreed to the compromise set forth in the Energy Policy and Conservation Act of 1975 was that it established the groundwork for phasing out of controls on domestic oils, thereby encouraging additional oil exploration and development within the United States. Ford promised that all controls on domestic oil prices would be phased out within 40 months of the bill's becoming law. Ultimately, Ford signed the bill because he recognized that vetoing it would have resulted in no action being taken in the areas of energy policy and conservation. Ford did acknowledge that additional legislative action would be required to establish natural gas policies to deal with immediate shortages and the need to increase supplies of natural gas in the United States. He urged Congress to act on his proposal to allow oil from the naval petroleum reserves to be used to promote energy efficiency and stimulate the commercial development of synthetic fuels.

Oil Embargo

Since the Industrial Revolution, Americans had been burning coal and oil in massive amounts. While the use of such fuels reduced labor and increased the standard of living, it had also resulted in a mounting dependence on imported petroleum products. On October 18, 1973, the Organization of Petroleum Exporting Countries (OPEC) initiated an embargo of Arab oil in order to hit back at the United States for supporting Israel during the Arab-Israeli conflict (1969–76). OPEC was created at the Baghdad Conference in September 1960 by



A gas station owner stands by his empty pumps in 1973. That year, an embargo coordinated by OPEC nations resulted in high gas prices and shortages, as well as unemployment and inflation. The crisis cost the U.S. economy an estimated \$10 billion.

the founding nations of Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela as a means of coordinating policy among oil-exporting nations and regulating the petroleum-export industry. The oil embargo continued until March 1974.

The impact of the embargo on the United States was immediate. Many people were forced to wait in long lines at service stations to fill their gas tanks, and a large number of stations began closing on Sunday to keep from running out of gas. The price of foreign oil rose almost 400 percent between October 1, 1973, and January 1, 1974, rising from \$3 per barrel to \$11.65 per barrel. The price at the pump skyrocketed from 35 cents a gallon to 56 cents a gallon. The impact was also felt far beyond the gas tank. Over the course of a year, utility bills rose by

nearly \$500. American production rates declined at the same time unemployment and prices rose. Inflation climbed from 6.2 percent in 1973 to 11 percent in 1974 before dropping to 9.1 percent in 1975. According to figures released by Secretary of State Henry Kissinger, the oil embargo cost the United States 500,000 jobs and more than \$10 billion in costs stemming from inflation. At the same time the American economy was taking a nosedive, oil companies were reporting huge profits, which rose as much as 82 percent between 1972 and 1973.

Devising Energy Policies

Under considerable pressure, Congress worked with President Richard Nixon to deal with the oil crisis. The Federal Energy Administration and the Energy Research and Development Administration were established to coordinate energy policy and activities. After Nixon resigned in August 1974 amid the Watergate scandal, Vice President Gerald Ford was elevated to the presidency. Anxious to help repair the damaged reputation of the Office of the President while dealing with the ongoing energy crisis, the Democrat-controlled Congress expressed its willingness to work with President Ford on developing a new energy conservation policy.

By January 1975, Ford had sent a plan to Congress, calling for cutting energy consumption and stimulating the economy through increasing the price of imported fuels by levying a \$3 per barrel import fee and lifting federal controls put in place by his predecessor. However, some congressional Democrats preferred taxing gas directly at the pump. Regional and political differences led to heated debates in Congress, resulting in what Jim Wright (D-Texas) called “a farcical comedy of frustrations.” The EPCA was introduced in the Senate by Henry M. “Scoop” Jackson, a Democrat from Washington State.

The House version of EPCA, the Energy Conservation and Oil Policy Act of 1975 (H.R. 7014) offered a more comprehensive energy policy than that proposed by the Senate. However, Republicans on the conference committee refused to sign it. In response to these regional and party differences, a number of compromises led to passage of the Energy Policy and Conservation Act of 1975, an energy plan that fully satisfied no one but did manage to steer the United States toward the development of new energy policies.

Two major provisions of the Energy Policy Conservation Act of 1975 were the creation of the Energy Research and Development Administration and the extension of insurance for the nuclear power industry in the United States. Congress removed the oil and gas depletion allowance supported by Ford and the Republicans from the final version the bill, which meant that oil companies were required to pay an additional \$2 billion in taxes.

Agencies and Standards

The Energy Policy and Conservation Act of 1975 expanded the authority of the Federal Energy Administration (FEA), assigning the agency responsibility for overseeing the mandated switch from oil to coal in major power plants and fuel-burning installations. The administrator of the National Highway Traffic Safety Administration was given authority to grant loans of \$30 million to \$750 million to encourage the development of underground coal mines. No more than 20 percent of such loans were to be used in the development of new high-sulfur coal mines. The secretary of the interior was charged with establishing rules governing bidding for rights to develop crude oil, natural gas, and natural gas liquids within the Outer Continental Shelf.

All automobiles manufactured or imported after 1977 were required to meet Corporate Average Fuel Economy (CAFE) standards. Those standards required that all such automobiles achieve the standard of operating at energy-efficient levels of at least 26 miles per gallon by 1985. The National Highway Traffic Safety Administration of the Department of Transportation was assigned authority to regulate CAFE standards.

Another provision of the Energy Policy and Conservation Act of 1975 launched a federal energy testing and labeling program that applied to all major consumer products manufactured in the United States. The EPCA gave the federal government the authority to audit any person or company that was required by federal law to submit energy information to any government body except the Internal Revenue Service. All vertically integrated oil companies were required to verify any information submitted in reports.

Oil Reserves

The EPCA also created a national strategic petroleum reserve of 1 billion barrels of oil and petroleum

to protect the United States for up to three months in case of another oil embargo. FEA was required to submit a Strategic Petroleum Reserve Plan to Congress by December 15, 1976. The plan was to include an environmental assessment and provide details on storage facilities, including costs, predicted impacts on petroleum prices, and plans for distributing the reserves whenever it became necessary. A plan for establishing an Early Storage Reserve was to be submitted on Congress within three months of passage of the EPCA, and Early Storage Reserves were to be set up in existing facilities in order to meet the needs of individual regions. Further, a Regional Petroleum Reserve was to be established within each Federal Energy Administration region. Under the leadership of the administrator of the FEA, an Industrial Petroleum Reserve was to be created by requiring all companies that imported petroleum products to store up to 3 percent of amounts imported or refined during the previous year. Congress appropriated \$100 million to be used in developing the Strategic Petroleum Reserve Plan and authorized necessary appropriations for the implementation of the Early Storage Reserve.

Presidential Standby Authority

The EPCA also gave the president of the United States the authority to control the flow of energy supplies. In order to do this, the president was given authority to restrict exports of energy supplies and energy-related items; oversee the allocation of scarce energy supplies; require an increase in oil and gas production; demand that refineries adjust proportions of fuel oil and refined products produced; and mandate the accumulation, maintenance, and distribution of oil and petroleum inventories at designated levels. While existing price controls on domestic oil remained in place until 1979, the act provided for those controls to be phased out, eventually being encompassed under the president's standby powers. Domestic oil prices were immediately rolled back to no more than \$7.66 per barrel.

The president's standby powers were to be used only in the event of an oil emergency or when necessary to fulfill the obligations of international agreements. The standby powers included the authority to initiate mandatory conservation measures and gas rationing. Both were subject to review by Congress. The president was required

to submit energy conservation contingency and rationing contingency plans to Congress within 180 days. Enactment of such plans was to be effective for no more than nine months, but rationing could be rescinded by the president at an earlier date. When exercising standing authority in the area of energy conservation, the president was required to inform Congress of the potential economic impact of such a plan, including its effects on major industrial sectors, employment, consumer prices, and the potential for anticompetitive effects. In the eventuality of imposing a rationing contingency plan, the president was required to submit a plan that prioritized the use of gas and diesel fuel according to classes of end users. Local boards were to be established to deal with petitions and the need for reclassification.

The EPCA was amended in 1988 by the Alternative Fuels Act. In this act, the focus became the development of alternatives to fossil fuels, such as ethanol, methanol, natural gas, liquefied petroleum gas, hydrogen, and electricity. This act also mandated the use of alternative fuel-burning vehicles in the federal fleet.

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See Also: Alternative Motor Fuels Act of 1988; Energy Costs; Federal Automobile Safety Standards; National Highway Traffic Safety Administration; U.S. Department of Transportation.

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Environmental Impacts

Like all forms of anthropogenic activity, transportation is accompanied by environmental impacts. The vast majority of transportation is based on the burning of fossil fuels. Exhaust emissions represent a major contributor to environmental degradation in the form of noxious gases, toxic compounds, and global warming. Altering the landscape and changing local land use to make way for a highway or airport can fragment ecosystems and destroy habitat. Facilities that support transportation from manufacturing to maintenance tend to be coupled with hazardous materials and waste that are harmful to the biotic community. Even loud noises from a train or jet airplane can be detrimental to the health of humans and wildlife. Until transportation breaks its bond with fossil fuels, the environmental impacts of this industry will continue.

Highways

Travel by highways is still the prevailing mode of transportation in the United States and has negative effects from roadkill to vehicle emissions. Road construction and maintenance requires the use of land that can potentially impact the environment through the disruption of natural habitat, modified hydrology, and contaminated runoff. While much of the nation's highway construction has occurred over decades, the impact on many habitats can still be felt in the form of fragmentation. In expanding urban areas road construction is ongoing and, depending on the sensitivity of the habitat, can have

significant consequences for local ecosystems such as wetlands. These wetlands may be made up of marsh, swamp, or mangrove and are beneficial for controlling floods and supporting species diversity. Construction site runoff can contribute to higher erosion rates accompanied by increased sedimentation, which can endanger aquatic habitats. Pollutants washed from roads can enter neighboring streams and lakes, affecting water quality. Repair shops, service stations, and maintenance facilities are sources of pollution in the form of gasoline, oil, and dirt runoff that enter waterways through the sewer system. Additionally, stormwater runoff is prevented from infiltrating paved surfaces and thus cannot replenish underground aquifers.

In large urban areas, 90 percent of the carbon monoxide (CO) and 50 percent of the ground-level ozone (O₃), a major component of smog, is attributed to vehicle exhaust. Automobiles emit nitrogen oxides (NO_x) and sulfur oxides (SO_x), which contribute to the formation of acid rain as well as volatile organic compounds (VOCs) and particulate matter, which are carcinogenic. It is estimated that the annual number of premature deaths in the United States due to vehicle emissions is about the same as the number of deaths each year from traffic accidents. Overall, automobile exhaust can adversely impact the environment by damaging forests, grasslands, and croplands. Perhaps the most insidious emission in vehicle exhaust is carbon dioxide (CO₂). CO₂ is the primary greenhouse gas that causes global warming. Approximately one-third of the CO₂ released in the United States is from the transportation sector and nearly one-quarter of this total comes from motor vehicles. The current global level of CO₂ is 394 parts per million (ppm) with an annual rate of increase of 2.15 percent. CO₂ emissions from the transportation sector have risen each year by approximately 2 percent since 1990. Carbon dioxide represents 95 percent of all the greenhouse gases released by the transportation sector, which includes methane, nitrous oxide, and various refrigerant compounds.

Railways

As a result of fossil fuel combustion, hazardous material spills, and noise pollution, rail transport can seriously impact the environment. The majority of locomotives in the United States are powered by diesel, which generates emissions similar as other

fossil fuels. These include CO, CO₂, VOCs, NO_x, SO_x, and particulate matter (PM). Some passenger trains are powered by electricity, which is generally touted as clean energy. However, unless the generating station powering the train is using a renewable resource such as wind or solar, the same emissions associated with burning fossil fuels can have a detrimental impact on the environment.

Noise is a common environmental nuisance often associated with rail transport, whether it is the blast of a train whistle, the clatter of wheels on the rail, or the blare of the engine. Researchers have established that outdoor sound levels higher than 65 decibels are unacceptable. The typical noise level of a diesel engine is 100 decibels, and the blast of a locomotive whistle can be as high as 120 decibels. Over time, daily noise levels from passing trains have been known to trigger muscle/gland reactions, impair motor skills coordination, and cause gradual hearing loss. Some 3 percent of the population in the United States is considered to be affected by noise levels from trains that are classified as annoying.

Due to the role played by railways in the movement of domestic freight, the potential for hazardous material spills is significant. Approximately 30 percent of the tonnage transferred across the United States is carried by freight trains. These trains haul hazardous substances including poisonous gases, flammable liquids, corrosive chemicals, and even radioactive materials. In the event of a hazardous spill that is not properly contained, there can be severe damage to the environment in the form of impacts on human health, habitat destruction, water and air pollution, and the loss of fish and wildlife. The gravity of a railway spill depends on factors such as the volume and toxicity of the material, regional topography, and the makeup of the indigenous flora and fauna. While hazardous material spills may impact a small local area, these negative effects can have far-reaching environmental consequences.

Airways

The aviation industry is currently expanding at an annual rate of 5 percent and this growth trend is expected to continue in the coming years. The majority of commercial aircraft cruise at altitudes above 33,000 feet, releasing NO_x directly into the upper atmosphere, causing a decrease in beneficial stratospheric ozone and increasing levels



Deicing fluid runs off the wing of this U.S. Army aircraft at Joint Base Elmendorf-Richardson in Alaska, January 2012. As much as 80 percent of deicing fluid, which is often made up of ethylene and propylene glycol, may end up running off into the soil around airports. An estimated 12 million gallons are used at airports in the United States every year.

of tropospheric ozone that could enhance global warming. As the airline industry continues to rapidly expand, NO_x emissions, which contribute to acid rain, will continue to escalate, affecting buildings, ecosystems, and wildlife. Water vapor released from the combustion of jet fuel results in the formation of contrails. These high-altitude cirrus clouds have been linked to global dimming, a decrease in the amount of solar radiation reaching the Earth's surface. Contrails have also been implicated in the formation of stratospheric clouds that are associated with the destruction of the ozone layer.

Among the environmental impacts of aviation at the surface is the runoff from the deicing of aircraft. Ethylene and propylene glycol are common ingredients in deicing formulas and are known to cause numerous biological problems. Approximately 12 million gallons of deicing substances are used annually in the United States and it is estimated that as much as 80 percent of this fluid runs off the wings onto the tarmac and eventually infiltrates the surrounding soil. Similar to diesel locomotives, jet aircraft engines also generate high levels of noise. It is estimated that at least 9 percent of the U.S.

population experiences annoying levels of noise from aircraft, which is cited as the most detrimental environmental impact related to aviation.

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See Also: Air Pollution, Automobiles; Airports, Environmental Issues and; Carbon Dioxide Emissions; Carbon Monoxide Emissions; Electric Diesel Locomotive; Hazardous Materials Transport; Health Issues; Nitrogen Oxides; Particulate Matter; Railroad Industry, Economics of; Smog; Sulfur Dioxide; Volatile Organic Compounds.

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Environmental Justice

Environmental justice (EJ), both a social movement and a field of inquiry, concerns itself with justice issues associated with both the distribution of environmental amenities and disamenities, as well as the processes of making decisions about the environment. In the context of transportation, EJ concerns include the distribution of transportation infrastructure and its appropriateness for residents, the distribution of the negative externalities from that infrastructure, and the associated decision-making processes.

What Is Environmental Justice?

Environmental justice emerged in the United States as a response to the unequal distribution of environmental hazards across social and geographical space; by the early 1990s, studies were finding locally undesirable land uses (LULUs) to be disproportionately located in poor communities and communities of color. The contemporary EJ movement coalesced in the 1980s after a series of key events. In 1978, after a truck driver intentionally dumped tens of thousands of PCBs on a roadside, Warren County (North Carolina), a predominantly African American community, was selected as the site for a landfill to dispose of the contaminated soil. This sparked a decades-long battle to first resist the siting of the toxic landfill and then to clean up the site.

In 1987, the United Church of Christ issued a comprehensive study of environmental justice that found minority status to be a strong predictor of LULU siting in the United States. The movement further developed in 1990 when activist and scholar

Robert Bullard published *Dumping in Dixie*, the first book-length treatment of this subject. EJ leaders from across the country met in 1991 for the First National People of Color Environmental Leadership Summit, where they laid out principles to guide the movement. While many EJ activists and groups continue to focus on LULU siting and cleanup, many also work on issues of transportation, food, education, and resource extraction, and are united by a concern for the public health and well-being of all people.

The role of transportation in environmental justice can be traced back to the civil rights movement, which responded to and engaged with transportation as a justice issue. Rosa Parks, perhaps the most iconic figure of the movement, used the public bus as a place to engage in civil disobedience. Her individual action spurred the Montgomery Bus Boycott (1955), in which African Americans stopped riding buses as a form of protest against segregated transit systems. Racial segregation on public transportation remained the norm in much of the southern United States through the 1960s when the Freedom Riders began riding interstate buses as a mode of protest against continued racist practices.

Several U.S. policies aim to address transportation concerns, environmental justice, and civil rights. Title VI of the 1964 Civil Rights Act prohibits the federal government from discriminating based on “race, color, or national origin.” Although EJ activists have attempted to use Title VI, recent court decisions have found that it can only be applied in cases of intentional discrimination, thus limiting its potential as an activist tool. In 1994, President Bill Clinton signed Executive Order 12898 on environmental justice, requiring federal agencies—including the Department of Transportation—to consider the impacts of their actions on low-income and minority communities. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1992 and its latest incarnation, the Moving Ahead for Progress in the 21st Century Act, include specific considerations of equity and fairness in allocation of transportation resources and public participation.

Uneven Access to Transit Amenities

In many urban centers, minority and low-income residents comprise the majority of public transportation riders—in 1995, 69 percent of U.S. bus



A resident of Portsmouth, Virginia, makes use of a new bike path in 2013. Minority and low-income residents often have less access to safe spaces for walking and bicycling. The path was created as part of a recent plan that took into account residents' demands for more pedestrian- and bicycle-friendly streets.

riders were minorities. Low-income and minority communities tend to rely on public transit, walking, and bicycling as transportation more than white and higher-income communities. Yet transportation funding, which is usually driven by congestion relief concerns, is heavily weighted toward roadways rather than bus and light rail systems. Even within public transit systems, there are funding disparities; cities tend to invest more readily in light rail than in bus systems, though bus systems are much more likely to serve low-income and minority residents.

In the 1990s, the Bus Riders Union formed in Los Angeles to protest the city's uneven investment in rail versus bus systems; the rail system then under construction and mostly serving white residents, was at the time consuming 70 percent of the regional transportation agency's annual transportation budget even though it met the needs of only 6 percent of public transit riders. Such uneven funding and transit access are exacerbated by the legacy of post-World War II land use practices, racist mortgage policies, freeway funding, and exclusionary zoning, all of which helped create urban cores in the United States that tend to be composed of poor and minority residents. Consequently, the spatial mismatch problem (that is, impractical distances between

where people live and work) is exacerbated in low-income and minority communities where residents rely on public transit or pedestrian infrastructure for transportation.

Minority and low-income residents may also have less access to roadways and walkways that are safe for walking and bicycling; thus African American and Latino residents are much more likely than their white counterparts to fall victim to pedestrian and bicycle-related deaths.

Negative Transit-Related Impacts

Evidence suggests that low-income and minority communities experience a disproportionate burden of the negative environmental impacts from transportation. Like other undesirable land uses, such as hazardous waste facilities, freeways often locate in low-income or minority neighborhoods due to a confluence of factors, frequently including low perceived opposition to construction, legacy of racist housing practices that led to segregated communities and disinvestment from urban cores, and low land cost. At the same time, pollutants from vehicles are often the most severe next to roads. The common air pollutants from vehicular traffic—particulate matter (PM), nitrogen oxides (NO_x), sulfur dioxide (SO₂), unburned hydrocarbons, and carbon monoxide (CO)—affect public health both locally and regionally. Many EJ studies have found that poor and minority communities are disproportionately affected by vehicle-related air pollutants and the resultant health problems, including asthma and cancer. These patterns hold true outside the United States as well; in a 2007 study of Christchurch, New Zealand, researchers Simon Kington and colleagues found that disadvantaged communities experience the highest level of pollution exposure from vehicles and that areas with high car ownership experience lower levels of exposure.

Roadway- and public transit-related light and noise pollution also often disproportionately affect these communities. While these may seem like mere annoyances, constant exposure to noise and light pollution can contribute to negative health impacts. Noise pollution can affect cardiovascular health, exacerbate health problems associated with stress, and possibly affect cognitive development in children. Light pollution may have negative effects on mood and cognition as well.

Pollution from diesel trucks has been particularly problematic, not just from truck routes but from idling vehicles. For example, in 1998, WE ACT was formed to address a multitude of environmental hazards, including six diesel bus depots, in heavily African American and Latino North Manhattan. Community groups such as WE ACT are concerned not only about the air pollution produced by idling vehicles but also about the threat such facilities provide to pedestrian safety.

Most environmental justice scholars would argue that unjust practices and processes help explain these unjust patterns of the distribution of transit amenities and disamenities. Some of these outcomes are the result of practices of the past, but some derive from decision-making processes that are undemocratic. In developing new transportation planning processes, many states and municipalities are beginning to recognize the importance of democratic, inclusive decision-making processes in creating a just transportation system.

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See Also: Air Pollution, Automobiles; Air Pollution/Air Quality; Civil Rights; Environmental Impacts; Executive Order 12898; Health Issues; Light Pollution; Noise Pollution and Cars; Public Participation in Transportation Planning; Social Equity and Discrimination in Transportation; Transportation and the Disadvantaged; Travel Patterns by Income; Travel Patterns by Race/Ethnicity.

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Environmental Protection Agency

The groundwork for the U.S. Environmental Protection Agency (EPA) was laid with the passage of the National Environmental Policy Act (NEPA), which was signed into law by President Richard M. Nixon on New Year's Day in 1970. Prior to NEPA, the role of government was seen as simply the conservation of natural areas due to the efforts of men such as Henry David Thoreau, John Muir, and Teddy Roosevelt. However, as industrialism expanded, it brought with it pollution and the exploitation of natural resources.

With the advent of the first Earth Day on April 22, 1970, millions of Americans made it clear that in their view the government should not only preserve ecosystems but also punish those who abuse and degrade nature. Thus, the EPA was established on December 2, 1970, in a reorganization move that sought to unite several government agencies under one director to safeguard the environment through research, monitoring, standards, and enforcement.

The overall mission of the EPA is to protect the environment and human health. The purpose of the EPA is to ensure the United States leads the world in this endeavor by establishing and enforcing federal laws designed to fulfill this mission; that these laws are based on sound science; that all aspects of society have access to the information necessary to manage health and environmental risks; that by protecting the environment, communities and ecosystems are both sustainable and productive; and that environmental policy also protects American economic interests, including industry, agriculture, and transportation.

Automobiles

Among the earliest challenges for the EPA was bringing automobile emissions into compliance with the standards of the Clean Air Act (CAA) of 1970, which established benchmarks for national air quality. At the time, the leading source of air pollution was the automobile. The new standard for automobile emissions was impressive, calling for carbon monoxide and hydrocarbon reductions of 90 percent by 1975 and nitrogen oxide reductions of 90 percent by 1976. The head of the EPA

directly asked all foreign and domestic automakers to explain how they intended to meet these goals. The manufacturers were required to appear at public hearings to describe the approaches being examined to meet the new standards, the issues yet to be addressed, and the major hurdles in implementing the standards. The EPA went so far as to ask how much money and manpower each manufacturer anticipated using to reduce emissions by 90 percent.

The automobile industry responded with the catalytic converter, which was first installed on cars in the mid-1970s. The converters enabled manufacturers to achieve the goals set by the CAA and have since reduced pollution by some 10 billion tons. The efficiency of the catalyst is greatly reduced by lead, which had the added benefit of encouraging the development of unleaded gasoline, further reducing the health hazards associated with vehicle emissions. Today, catalytic converters are installed on more than 500 million vehicles worldwide, from motorcycles to buses, and are capable of decreasing emissions from the combustion of diesel, propane, and natural gas as well as gasoline. The passage of the CAA and the invention of the catalytic converter marked the EPA's first major victory in the battle against air pollution that continues to this day.

Railroads

Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976, which was aimed at conserving natural resources and energy while reducing the hazards associated with waste disposal and the amount of waste generated. In 1984 the act was amended to require all facilities that treat, store, or dispose of hazardous waste to clean up their sites, including most railroad transportation facilities.

An environmental group, the Natural Resources Defense Council (NRDC) brought a suit against the Union Pacific Railroad and BNSF Railway in 2011, alleging that diesel exhaust is a hazardous waste that should be regulated by the EPA in accordance with the RCRA. The group claims that particulates from the locomotives have been linked to respiratory and cardiovascular disease, cancer, and premature death. The NRDC blames certain railroad yards in California for cancer rates in neighboring communities that are as much as 50 times higher than the

national average because the railroads have failed to upgrade to newer, less polluting locomotives in an effort to cut costs. The railroad companies responded that the suit was an attack on the goods industry and that rail is the most environmentally favorable mode of transportation. The lawsuit was filed in federal court, and at the time of this writing a decision had not been reached.

Shipping

The first major law aimed at controlling water pollution was the Federal Water Pollution Control Act passed in 1948. With the establishment of the EPA and a growing concern for protecting the environment and human health, the Clean Water Act of 1972 amended the 1948 law, giving the EPA the power to implement pollution control programs and prosecute those who discharge pollutants into navigable waters. The cruise ship industry is among those under the watchful eye of the EPA.

A typical cruise ship carries thousands of passengers and is literally a floating city, with the same environmental and health concerns of any community. The primary concern of the EPA in regard to cruise ships is the discharge of waste, which includes sewage, graywater, bilge water, solid waste, and hazardous waste. To address these issues the EPA has developed a cruise ship assessment report that measures the volume of each of these five waste streams, addresses ways to best manage and treat waste, examines the negative impacts associated with waste, and considers federal regulations already in place as well as those that need to be implemented in order to address cruise ship waste.

Perhaps the vilest of vessel discharges, whether it is from a sailboat or a cruise ship, is sewage. In addition to nutrients, sewage can contain solids, toxins, heavy metals, pathogens, and endocrine disrupters. As a result, sewage is capable of impacting both the aquatic environment and human health, especially in confined areas such as lakes and marinas. In addition to regulation and enforcement, the EPA recommends that vessels owners, operators, and passengers do their part to mitigate the effects of sewage discharge by minimizing the use of water, by not littering waterways, by not improperly disposing of wastes in toilets and sinks, and by recycling. These acts represent simple, effective means of reducing the sewage waste stream.

Aviation

The global demand for aviation transportation is predicted to increase rapidly in the coming years. Keeping up with this demand will require increased efficiency, an upgraded infrastructure, and compliance with the Clean Air Act. For example, nitrogen oxide (NO_x) is emitted when fossil fuels are burned and has been linked to lung disease and respiratory infection.

The International Civil Aviation Organization (ICAO) has adopted strict emissions standards for NO_x and the EPA has followed suit with new standards that apply to most large commercial aircraft that could dramatically reduce NO_x emissions by 2030 in the United States.

Likewise, leaded aviation fuel, or avgas, which is used by general aviation aircraft, is the largest source of lead contamination in the United States despite the known risks associated with lead poisoning. However, although the EPA has eliminated leaded gas from motor vehicles, it has failed to act on avgas to the dismay of environmentalists.

Similarly, the EPA concluded in 2009 that greenhouse gas emissions, including carbon dioxide (CO_2), pose a risk to the environment and human health under the Clean Air Act. The EPA established standards for cars and trucks that were challenged by various industry groups. The endangerment finding regarding cars and trucks made by the EPA was upheld by a federal appeals court in June 2012.

Nevertheless, the EPA has stated that a new endangerment finding would have to be conducted concerning greenhouse gas emissions from aircraft, which could take years to conduct. The EPA argues that aviation accounts for only 2.5 percent of CO_2 in the United States and that the agency is more concerned with larger sources of greenhouse gas pollution, such as motor vehicles.

Environmental groups are outraged at the delay but are forced to play a waiting game, knowing that eventually the EPA will have to acknowledge that aviation, like all forms of transportation based on the burning of fossil fuel, emits pollutants that are harmful to human health and the environment.

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See Also: Air Pollution, Automobiles; Air Pollution/Air Quality; Airports, Environmental Issues and; Alternative Automotive Fuels; Alternative Fuels; Carbon Dioxide Emissions; Clean Air Act and Amendments; Green Transportation; Greenhouse Gases; Railroad Industry, Economics of; Ships; Sustainable Transportation; Vehicle Emissions Standards.

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Environmental Quality Improvement Act of 1970

The Environmental Quality Improvement Act of 1970 (P.L. 91-224) strengthened the Council on Environmental Quality (CEQ), which had been created the previous year when Congress passed the National Environmental Policy Act. The director of the Council on Environmental Quality is chosen by the president and confirmed by the Senate, and the CEQ has cabinet-level status. The Environmental Quality Improvement Act of 1970 (EQIA) spelled out the responsibilities of the director. Those responsibilities include coordinating environmental policy throughout the federal government and mediating any disputes that arise when governmental bodies come into conflict.

President Richard Nixon supplemented EQIA by issuing Reorganization Plan Number 3 in which he redistributed responsibilities for overseeing different aspects of environmental protection. The Environmental Protection Agency (EPA) was created

and charged with centralizing pollution control. The Federal Water Quality Administration and the National Air Pollution Control Administration were moved from the Department of Health, Education, and Welfare to the EPA. Other agencies that held environmental responsibilities also were transferred from the Department of Agriculture and the Department of Interior to the EPA.

Although Congress passed the Environmental Quality Improvement Act of 1970 unanimously, the battle between environmentalism and “Big Business” was far from over. It continued to rage with fervor during the 1980s and heightened even further in the 1990s. With the election in 2000 of President Barack Obama, however, the CEQ was given significant support for fulfilling its intended role.

Background

In 1969, Congress passed the National Environmental Policy Act, and President Nixon signed it into law on January 1, 1970. The act was an official acknowledgement that irresponsible behavior had led to significant damage to the environment of the United States. Passage of the law set the nation on a new path in which protecting the environment became a major priority. The act also created the Council on Environmental Quality (CEQ), which oversees federal policies and programs related to the environment.

In 1962 Rachel Carson released her indictment of irresponsible behavior that played havoc with the environment, *Silent Spring*. The book provided motivation for the emerging environmental movement. Then on June 22, 1969, a rail car passing through the industrial section of Cleveland, Ohio, released a spark that sent a wake-up call around the country. When the spark reached an oil slick on the Cuyahoga River, it set the river ablaze, destroying two railroad bridges and amassing damages of some \$100,000. The oil slick was the result of decades of industrial dumping by the Republic Steel Mill. *Time* magazine featured the story of the fire on the Cuyahoga River, including a photograph of a fire that had actually occurred on the river in 1952. Cleveland became a symbol for environmental irresponsibility. However, Cleveland was not alone in degrading the environment.

Oil spills were becoming increasingly common in the United States, and beaches were also being

polluted by grounded tankers. Wildlife habitats were being destroyed in the name of progress, and the agricultural sector had polluted both land and water with DDT and other pesticides. As the 1960s with their emphasis on social revolution gave way to a new decade, the environmental movement continued to gain support.

In 1970, many Americans were up in arms over what they considered governmental disregard for the environment. Pressure mounted at the national, state, and local levels, with environmentalists urging legislatures to enact laws to improve environmental quality in the United States. The official launching of the American environmental movement is considered to be the first Earth Day, celebrated on April 22, 1970. On that day, some 200,000 people gathered at the National Mall in Washington, D.C. Smaller groups also gathered throughout the country to demonstrate the strength of the environmental movement.

Responding to the pressure, Congress and President Nixon worked together to create a national policy on environmental protection. That same year, the EPA was established to take on the responsibility of overseeing the process of forced compliance to new environmental laws.

Provisions

In the introduction to the Environmental Quality Improvement Act of 1970, Congress expressly acknowledged that the environment had suffered at the hands of humans and that population increases and urbanization had heightened that damage through pollution and environmental degradation. While stating that the chief responsibility for mitigating the negative impacts of irresponsible human behavior must necessarily reside at the state and local level, Congress accepted the responsibility of the federal government to assist in those endeavors.

A major provision of the bill concerned establishing environmental protection guidelines for all federal departments and agencies involved in public works projects. The act also bolstered the authority of the Office of Environmental Quality and assigned it responsibility for providing professional and administrative staff for the Council on Environmental Quality.

The chair of the Council on Environmental Quality was named as the director of OEQ, and the act

stipulated that a deputy director be appointed by the president and confirmed by the Senate. Responsibilities of the director included employing up to 10 environmental experts and consultants. The director was specifically assigned the responsibility to assist and advise the president on policies and programs dealing with environmental quality. In order to do this, the director was also charged with assisting other federal agencies in evaluating the effectiveness of existing policies and programs related to environmental quality, making recommendations for improving existing methods for monitoring and predicting environmental changes, promoting research into the ways that science and technology could be used to prevent or reduce the impact of damage to the environment, and assisting other departments and agencies in establishing their own standards for improving environmental quality. The director was also given responsibility for collecting, collating, analyzing, and interpreting data dealing with all aspects of environmental quality. Another provision of EQIA required the director of the CEQ to submit an annual Environmental Quality Report to Congress.

The director was instructed to work with the general public in carrying out his/her duties. EQIA also established funding for implementing the provisions of the act, and Congress appropriated \$2.126 million per year through 1979. Additional funds were appropriated to keep the CEQ functioning through 1985.

Aftermath

In the 1970s, much of the pollution affecting both air and water was caused by toxins regularly released by industrial plants. After the passage of EQIA, those plants were required to install filters that prevented pollution from smokestack and wastewater pipes being released into the environment. Small businesses and farms, on the other hand, were not always bound by environmental quality laws. In 1995, in a report for the *Congressional Quarterly*, Mary Cooper stated that despite laws mandating improved environmental quality, two out of every five Americans still lived in areas that were clogged by urban smog. One out of four also lived within four miles of a toxic dump.

One of the reasons for regression in the area, in Cooper's view, was the backlash from states following the 1990 amendments to the Clean Air Act.



Runoff from a landfill operation enters a creek that runs into the Cuyahoga River, 1973. The Cuyahoga River and Cleveland, Ohio, became a symbol of environmental degradation in the late 1960s and early 1970s as the environmental movement grew.

That act, which was passed the same year as the Environmental Quality Improvement Act, established regulations governing emissions of 189 known pollutants, mandated the use of antipollution equipment in industries, and forced automobile manufacturers to install catalytic converters in all motor vehicles.

Between 1970 and 1990, emissions of particulates declined from 25 million tons per year to less than 10 million tons per year. Other laws were passed to deal with water pollution and environmental conservation. Much of the backlash of the early 1990s resulted from the lobbying efforts of the logging, mining, and livestock industries.

When Republicans swept into Congress in November 1994, Speaker of the House Newt

Gingrich (R-Georgia) announced that the party had signed a “A Contract With America,” granting the Republican Party a mandate to rid the nation of laws passed by decades of Democratic lawmakers. Despite the fact that 80 percent of Americans identified themselves as environmentalists by that time, some Republicans attempted to undo two decades of environmental protection laws, claiming that they infringed on the rights of states and the business sector.

Within the first 100 days of taking control of both the House and the Senate for the first time in four decades, the Republican Congress considered 10 bills that contained elements that could have drastically altered the environmental landscape in the United States. Those proposed bills included the Private Property Rights Protection and Compensation Act, which would have prevented the government from enforcing environmental, health and safety protections; the Risk Communication Act, which would have allowed scientists hired by particular industries to proclaim publicly that current environmental laws were based on “bad science”; the Federal Regulatory Budget Cost Control Act, which would have limited the number of federal regulations allowed during a designated period; and the Administrative Procedure Reform Act, which would have subjected all federal regulations, included those that protected the environment, to intense scrutiny by the Office of Management and Budget (OMB).

CEQ Initiatives

Despite the 1990s attempts by ultraconservative Republicans to undo the impact of the Environmental Quality Improvement Act of 1970, along with other environmental legislation, the authority assigned to the Council on Environmental Quality under EQIA has allowed the agency to continue to carry out its responsibility to protect the environment of the United States. In 2013, one of the major initiatives being carried out by CEQ involved federal sustainability.

Federal sustainability efforts include promotion of “green government.” In October 2009, President Obama signed the Executive Order on Federal Sustainability, which instructed all federal departments and agencies to reduce greenhouse pollution; established targets for energy, water, and waste reduction; and mandated the use of environmentally

friendly products and technologies. In 2011, the CEQ worked with the OMB to generate “Sustainability and Energy Scorecards” for federal agencies for the first time in U.S. history.

Other CEQ initiatives included America’s Great Outdoors Initiative, the National Ocean Council, Recovery Through Retrofit, and Commitment to Clean Water. Launched in 2011, America’s Great Outdoors Initiative promotes efforts to guarantee a clean environment for the children of today as well as those of the future by providing parks and community areas; restoring rivers and waterways; supporting farmers, ranchers, and other landowners in environmentally responsible activities; and reinvesting revenues generated from oil and gas extraction to provide permanent protection for parks, open spaces, wildlife habitats, and recreational areas.

The National Policy for the Stewardship of the Ocean is President Obama’s plan to improve the environment of the ocean, the coasts, and the Great Lakes. Recovery Through Retrofit targets homeowners, providing them with information on energy-related issues and offering them financial incentives to take energy-saving actions. The initiative also promotes training and jobs for individuals interested in home energy retrofits. Among its many efforts to ensure clean water in the United States, the Commitment to Clean Water Initiative promotes partnerships with states, local governments, and Native American tribes to restore bodies of water such as the Chesapeake Bay, the California Bay-Delta, the Great Lakes, the Gulf of Mexico, and the Everglades.

The Council on Environmental Quality serves, along with the Office of Science and Technology Policy and the National Oceanic and Atmospheric Administration (NOAA), as cochair of Obama’s Interagency Climate Change Adaptation Task Force. Membership is comprised of representatives from 20 federal agencies. The task force is charged with developing recommendations for policies and programs designed to prepare the United States for dealing with the effects of climate change.

In response to the havoc created by the Deepwater Horizon oil spill on May 24, 2010, along the Gulf Coast, President Obama created the Louisiana-Mississippi Gulf Coast Ecosystem Restoration Working Group, which is cochaired by the

Council on Environmental Quality and the Office of Management and Budget. Senior-level officials from NOAA, the EPA, the Department of the Army, the Department of Homeland Security, the Department of the Interior, and the Department of Transportation comprise the remaining members. The group released the Roadmap for Restoring Ecosystem Resiliency and Sustainability in the Gulf area on March 4, 2010.

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See Also: Air Pollution/Air Quality; Clean Air Act and Amendments; Environmental Impacts; Environmental Justice; Environmental Protection Agency; National Environmental Policy Act.

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Equilibrium Modeling

Equilibrium modeling, which also refers to the computable general equilibrium (CGE) model or applied general equilibrium (AGE) model, is a quantitative method primarily used for economic and policy impact analysis. The method has gained increasing attention and interest in recent decades due to the development of computer technology. In the field of transportation, equilibrium modeling has been extensively used to evaluate social, economic, and environmental impacts of infrastructure investment as well as various transportation-related price policies. This introduction to equilibrium modeling covers its definition, history, data, method, model types, implementation, and limitations.

Definition

General equilibrium model is a comprehensive economic model that uses actual economic data to estimate interactions between the economy and the changes in policy, technology, or other external factors. Unlike partial equilibrium modeling, general equilibrium modeling presents a more comprehensive impact assessment because both the demand and the supply of an economy are considered simultaneously in a system of equations with linkages through price and quantity of commodities. The model is built based on the Walras-Arrow-Debreu theory of general equilibrium, with modern modifications and extensions allowing for imperfect markets. Because CGE provides clear linkages between the microeconomic structure and the macroeconomic environment, the model can be applied to simulate the interrelationships among multiple industrial sectors and markets. More importantly, it can be used to assess direct, indirect, and induced effects from the change of public policy on various economic variables such as industrial outputs, employment, prices of commodities and factors, household income, and social welfare.

In CGE models, different economic agents, such as consumer, producer, government, investment, and the rest of the world, are usually included in the general equilibrium framework. Economic linkages between agents are established and modeled through simultaneous equations. A final solution for the equation systems is found through an algorithm of calculation under the condition of a general equilibrium. To achieve the impact assessment,

a new equilibrium solution is calculated based on revised or adjusted policy inputs or parameters. Impact variations can be measured by the differences of outputs between the new equilibrium and the prior base equilibrium.

History

The first CGE model was developed by the Norwegian economist Leif Johansen in 1960. His model is distinguished from traditional economic models in that the economic behaviors of different agents are modeled separately but with coordination through prices and quantities determined by interaction of demand and supply. In the 1970s, the American economist Herbert Scarf further improved the equilibrium modeling techniques by developing a mathematic algorithm for computing solutions to numerically specified general equilibrium models. His contribution is the design of the finite convergence approach that makes the computational process of equilibrium modeling achievable in a finite numbers of steps. After 1980, interest in equilibrium modeling expanded as applied researchers began to appreciate the power of optimizing assumptions that translated broad experience into plausible predictions of particular shock effects. In addition, the development of computer technology as well as improvement of economic data collection made CGE analysis much easier than before. In terms of modeling capacity, it is now possible to conduct a CGE analysis with 500 industries, 50 regions, and 700 occupations.

By the early 1990s, CGE modeling became an established field of applied economics. Many journal articles, monographs, and books became available that facilitated knowledge expansion and further applications of equilibrium modeling. Applications of equilibrium modeling experienced several transformations: it has been expanded from single-region model to multiregional model, from static model to dynamic model, from a trade-specific model to a general model enabling the analysis of all kinds of issues, including tariff, tax policy, environmental policies, technology, and transportation.

Social Accounting Matrix

Equilibrium modeling requires a large data input. All data for the analysis has to be constructed in the form of a social accounting matrix (SAM). A SAM

represents the flows of all economic sector interactions that occur within an economy. It provides a static picture of the economy at a point in time. The conceptual structure of a SAM is illustrated in Table 1. A SAM contains information on industrial activities and commodities, which is obtained from different resources, such as an industrial input-output table, national fixed-asset accounts, government finance, import and export trade flow survey data, and other data resources.

The structural characteristics of SAM can be illustrated as Benjamin H. Mitra-Kahn from the New London School, UK, has done:

SAMs are square (columns equal rows) in the sense that all institutional agents (Firms, Households, Government and “Rest of Economy” sector) are both buyers and sellers. Columns represent buyers (expenditures) and rows represent sellers (receipts). SAMs were created to identify all monetary flows from sources to recipients, within a disaggregated national account. The SAM is read from column to row, so each entry in the matrix comes from its column heading, going to the row heading. Finally columns and rows are added up, to ensure accounting consistency, and each column is added up to equal each corresponding row.

To build a SAM for equilibrium modeling can be very challenging as the process of data collection and compilation is cumbersome. Sometimes the process can be prohibitive because some economic information may not be available. This situation is especially common for equilibrium modeling at the regional level because the input-output data of SAM is often available only at the national level. A regional-level input-output table needs to be built before the implementation of the regional-level equilibrium assessment. Industrial flows at the regional level have to be either estimated based on sector shares or collected through a regional sector survey.

Fortunately, two data alternatives have been made available by an academic institution and a commercial company for equilibrium modelers. If the analysis is conducted at a national or continental level, Purdue University’s Global Trade Analysis Project (GTAP) database is advantageous. By using input-output tables and other economic data

Table 1 Conceptual structure of a social accounting matrix

Receipts	Activities	Commodities	Factors	Households	Government	Savings/ Investment	Rest of the World	Total
Activities		Marketed outputs						Gross output
Commodities	Intermediate inputs			Household consumption	Government consumption	Investment	Export	Demand
Factors	Value added							Factor income
Households			Factor income to house- hold					Household income
Government	Producer taxes, value added tax	Sales taxes, tariffs, export taxes		Transfers to government, direct				Govern- ment income
Savings- Investment				Household savings			Foreign savings	Savings
Rest of the World		Imports						Foreign exchange outflow
Total	Activity	Supply expenditures	Factor expendi- tures	Household expenditures	Government expenditures	Investment	Foreign exchange inflow	

Source: Zhenhua Chen

contributed by hundreds of researchers throughout the world, a worldwide database for equilibrium modeling covers trade between more than 129 countries or regions and 57 commodities. The database contains complete bilateral trade information, transport and protection linkages, and can provide national level or aggregate multicountry SAMs using the data software GTAPAgg. The latest version—GTAP 8—was released in 2012. The data includes dual reference years of 2004 and 2007 as well as 129 regions for 57 commodities. A user license has to be purchased in order to use the GTAP database.

If the analysis only has a focus on regions in the United States, the IMPLAN database is the other alternative for equilibrium modeling. The IMPLAN

database, developed by MIG, Inc., offers region-specific data information that can be used to create SAMs at various scales from zip code to U.S. state. Unlike the GTAP database, which is sold as a whole, IMPLAN data is sold separately for different regions or scales.

Methodology

Generally speaking, an equilibrium model is a simultaneous equation system that normally consists of equations representing various economic relationships for different economic agents, such as producer, household, government, and foreign economy. Each agent interacts with others while maximizing its utility or profit under budget constraints. The analytical process includes parameter

calibration and policy simulations. In the first step, key parameters in the equilibrium model are calibrated through inverse equations based on initial economic information from a SAM. The calibration is conducted under equilibrium given all the information from a SAM representing a real equilibrium economy.

In the second step, a new equilibrium is computed through the simultaneous equations and by adopting calibrated parameters. Impacts of output are calculated after adjusting some of the input variables or the so-called policy variables. Impact changes are measured by the differences between new outputs and initial outputs. Some specific characteristics of equilibrium modeling for each economic agent are discussed below.

Household. According to Walrasian neoclassical theory, a household is assumed to maximize its utilities under budget constraints. The household utility function is the backbone of household equation systems. It can be specified in various forms based on the specific theory or the focus of research. Depending on different assumptions of substitution rates, utility functions can be specified either in a Cobb–Douglas (CD) form with constant returns to scale, or as a Stone–Geary form with constant elasticity substitution (CES). In addition, equations representing household income, household consumption expenditure, and commodity consumption need to be specified with connections to other agent blocks.

Producer. The producer is assumed to maximize profit or minimize production cost. Producers create value added through a technology specified as a production function. Depending on the specific assumption on substitution relations between factors and intermediate inputs, production functions can be represented in various forms such as CD production functions, CES production functions, or Leontief production functions (Leo). The process of production can be modeled in numerous nested structures according to the different purposes of analysis. Because equilibrium modeling is capable of differentiating different sectors in a disaggregate framework, each sector is assumed to produce one commodity and maximize its profit or minimize its cost under a nested production structure, with capital, labor, and inter-industry flows as factors of production.

Government. Government plays dual roles in equilibrium modeling. On one hand, government functions as a consumer, who allocates government expenditure to purchase various industrial outputs.

On the other hand, government collects revenue through various taxes. Equations of the government block involve both revenue equations and expenditure equations. Revenue equations normally include import tariff taxes, export tariff taxes revenue, sales taxes revenue, and indirect taxes revenue. Expenditure equations include government commodity consumption and government expenditure.

Trade. Trade is modeled using the Armington assumption under the hypothesis of imperfect substitution between domestically produced and imported goods, which can be represented by a one-level CES function. In addition, exports are assumed to be imperfect substitutes for domestically produced goods and this can be represented by a one-level constant elasticity transformation function.

Market clearing. Market clearing in equilibrium modeling includes a set of equilibrium conditions as follows:

- Market equilibrium of goods requires equilibrium on both quantity and value.
- Assuming no labor migration or institutional barriers, market equilibrium of factors requires equilibrium in the labor market.
- Equilibrium in the capital market requires that the total social investment equals total social saving.
- Government budget equilibrium requires that the budget deficit equals the difference between governmental revenue and expenditure.
- Assuming personal income only comes from wages and interest on savings, the personal balance equilibrium indicates that personal savings must be equal to the difference between personal income and expenditure.
- International market equilibrium requires that the foreign deficit represent inflows of

foreign capital, while foreign savings represent outflows of domestic capital.

In addition, in practice, a slack equation for Walras's law is usually added in the simultaneous system to check that Walras's law is not violated during the calculation. To guarantee that an equilibrium solution is achieved, certain model closure rules are applied. The total number of variables must be equal to the numbers of equations so that solutions can be found. This requires numerical specification in the modeling process.

Types of Equilibrium Models

The applications of equilibrium modeling in the transportation field are extensive. The method is able to evaluate impacts of infrastructure investment, regulations, pricing externality, and other kinds of transportation policies. Each equilibrium model is different from the others due to the differences of exogenous parameters, SAM, and structures of simultaneous equations. The modeling techniques are developed in different types of forms for different evaluation purposes. The following sections introduce three types of equilibrium models: single region CGE, multiregional CGE, and dynamic CGE.

Single region CGE. A single region CGE is a basic equilibrium model. It models a single region without considering interregional economic linkages. In general equilibrium modeling literature, the single region CGE is the most common equilibrium model. It has been widely used to evaluate various policy impacts. The single region International Food Policy Research Institute (IFPRI) model is of this kind. The model was developed by Hans Löffgren, Rebecca Lee Harris, and Sherman Robinson in 2002. One of the major model characteristics is that transportation costs were explicitly modeled as part of the trade transaction costs. This is achieved by creating a separate account in SAM that indicates transaction costs for each specific activity. The model enables assessment at the national economy of impacts due to variations of transportation costs.

Multiregional CGE. Equilibrium modeling of transportation has been widely applied in a multiregional CGE. This is because issues such as trade relations and factor mobility are very difficult to

analyze under a single region model. The structures of multiregion in equilibrium modeling with spatial dimensions enables researchers to quantify interregional flows with relations to transportation inputs, which thus facilitate the assessment of spatial impacts of transportation facilities or policies. Due to this multiregional consideration, this type of equilibrium model sometimes is named spatial CGE, or SCGE.

The examples of multiregional CGE in transportation infrastructure impact assessments are extensive. Dr. Eduardo Haddad from the University of São Paulo, Brazil, and Geoffrey Hewings from the University of Illinois, Urbana, assessed the short-run spatial impacts of transportation investment in Brazil using a multiregional CGE model called B-MARIA-27. The model includes 27 Brazilian states, eight sectors, one household in each state, regional governments, one federal government, and a single foreign consumer. By applying nonconstant returns to scale in the manufacturing production function and non-iceberg transportation costs, their model found asymmetric impacts of transportation investment on a spatial economy in Brazil.

Pingo is another multiregional CGE model developed by Norwegian scholar Olga Ivanova. The model provides forecasts on regional and interregional freight transport and evaluates its impact for the Norwegian economy. The model consists of 19 regions and 10 sectors. After calibration based on a multiregional SAM, the model forecasts impacts of transportation infrastructure based on the future values of demand.

Johannes Bröcker from the University of Kiel in Germany developed another multiregional CGE called CGEurope. The model is used primarily to evaluate spatial economic impacts of transportation networks in Europe. The model is more complex than Pingo because it contains a total of 1,341 regions and six sectors, including one sector producing transport service. Unlike the B-MARIA-27 model that treats the economy as an imperfect market, CGEurope includes separate assumptions on the trade market, where the Dixit-Stiglitz fashion of monopolistic competition is assumed while local markets are assumed to operate under perfect competition.

A similar multiregional CGE model called RAEM was developed primarily by Jan Oosterhaven from the University of Groningen in the

Netherlands. RAEM is a Dutch SCGE model that includes one household, 14 sectors, and 548 regions in the Netherlands. The model has been applied to compare and evaluate economic impacts of two different magnetic levitation railway proposals in the Netherlands at different macroeconomic scenarios. Impacts on labor mobility and economic benefits were observed in the assessment.

Dynamic CGE. All the previously introduced CGE or SCGE are static models because they can only measure impacts and model the economy at one point in time. In recent years, equilibrium modeling has been expanded from static to dynamic models. These models are more realistic, as the dynamic specification traces each variable through time. But they are more difficult to construct and solve because they require future changes to be forecast for all exogenous variables, even those that are not direct parts of the policy change. For example, the change elements can result from partial adjustment processes or from stock/flow relations: between capital stocks and investment or between foreign debt and trade effects. Despite these advantages, dynamic CGE has a potential problem. The variables that change from one equilibrium to the next may not necessarily be consistent with each other.

To deal with the inconsistent problem, the recursive-dynamic CGE model is developed, which traces out a time path by sequentially solving a static model, one period at a time. The assumption is that behavior depends only on current and past states of the economy. Alternatively, if agents' expectations depend on the future state of the economy, it becomes necessary to solve for all periods simultaneously, leading to full multiperiod dynamic CGE models. Within the latter group dynamic stochastic general equilibrium models explicitly incorporate uncertainty about the future.

Xinshen Diao, a senior research fellow at the International Food Policy Research Institute, and economist Agapi Somwaru from the Economic Research Service at the U.S. Department of Agriculture developed an intertemporal general equilibrium model to evaluate the trade reform between the United States and the Southern Common Market, including four South American countries (MERCOSUR). This is a multiregional dynamic CGE model, as behaviors of consumers and firms are intertemporally optimized. The

model helps observe significant shifts of trade diversion away from nonmember trading partners to member countries.

MONASH is another multiregional, multisectoral dynamic CGE model system that allows for different choices of the levels of sectoral and regional disaggregation. The model was developed by Peter Dixon and Maureen Rimmer from Monash University, Australia. MONASH models the Australian economy in 112 sectors by 57 subnational regions, 340 occupations, and numerous types of households. It is a dynamic model because it allows different assumptions on the economy over a 20-year period. It also allows different assumptions regarding which variables are exogenously given and which are endogenously determined, depending on the researched economic situation. Transportation sectors in this model are treated as marginal sectors where the costs are imposed on the purchase price of goods (tradables) in trade and service. Dynamic impacts on the full economy from the changes of transportation cost in any particular year can be evaluated.

Implementation

Equilibrium models can be implemented in numerous software packages. The models can be implemented in advanced programming software such as C++ and Visual Basic. It can also be developed in specific equilibrium modeling software such as GEMPACK and GAMS.

General Equilibrium Modeling PACKage (GEMPACK) is a suite of economic modeling software developed by Mark Horridge from Monash University, Australia. The package can be used for a wide range of economic behavior under general equilibrium and contains capabilities for solving complicated models such as recursive-dynamic and fully intertemporal models. Based on the GEMPACK platform, the GTAP group designed a standard multiregional and multisector CGE model that specifically caters to the GTAP database called RunGTAP. The model allows researchers to conduct country-level equilibrium simulations directly using the GTAP database without having knowledge in CGE programming. The latest version of GEMPACK is 11.1 released in 2012.

The next professional software for equilibrium modeling is General Algebraic Modeling System (GAMS). Originally developed at the World Bank,

GAMS provides solution algorithms for simultaneous linear and nonlinear equations. It consists of a language compiler and a stable of integrated high-performance solvers. The software allows for complex, large-scale equilibrium modeling applications and enables modelers to build large maintainable models that can be adapted quickly to new situations. Besides the basic GAMS platform, many specific solvers with advanced algorithms are developed separately that can be used for more complicated equilibrium modeling. Since GAMS allows executing codes including up to 300 variables without a commercial license, any student and researcher can download the trial version at <http://www.gams.com> and use it for free.

Limitation of CGE

Despite its rigorous capacity to measure policy effects on the economy, CGE models have the following limitations that are insurmountable. First, simulation results of equilibrium models rely on an assumed economic environment; in other words, the model is nonconditional. This means that although the purpose of general equilibrium modeling aims to model the real economy, it can never complete the goal due to the dynamic and complicated nature of real economic environments and relationships.

Second, the rationale of equilibrium modeling is to compare a simulated outcome from shocks of policy variables with the base outcome without any policy variation. Results of equilibrium modeling sometimes may be deceptive and sensitive given the fact that various determinants such as exogenous parameters, structures of equations, and values in SAMs may have influences on the simulation outcomes. Improving the reliability of parameter estimations for equilibrium modeling is important, but more importantly, the results of equilibrium models should be treated with caution and further applications or generalization must also be used cautiously.

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See Also: Economic Development; Environmental Impacts; Full-Feedback Modeling; Networks Modeling; Transportation, Economics of; Transportation Modeling and Planning Software; Travel Modeling.

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E-Shopping

E-shopping, or online shopping, is the act of purchasing products or services over the Internet. The Internet has had, and continues to have, a profound impact on transportation systems and planning for future transportation networks as more and more

business-to-business (B2B), business-to-consumer (B2C), and consumer-to-consumer (C2C) transactions are conducted through e-commerce.

E-commerce can be defined as doing business over the Internet and refers to transactions that take place between organizations and people in societies. This method of shopping has been in existence for over a decade and, with the ever-expanding penetration of the Internet around the globe, it is unsurprising that e-shopping is increasingly popular among consumers and retailers around the world. With the advent of information and communication technologies (ICT) and online shopping have come new types of activity and travel patterns.

At present there are over 2 billion Internet users worldwide, and this number is predicted to rise to 3 billion by 2015. Global B2C e-commerce industry generated somewhere between \$400 billion and \$600 billion in 2010. According to 2013 figures from the eMarketer, North America currently has the largest market for B2C ecommerce. However, the BRIC countries' (Brazil, Russia, India, and China) share of online sales is growing rapidly, with forecasts suggesting that by 2015 Asia-Pacific will surpass North America in terms of B2C e-commerce spending. This rapid growth reflects the rise of Internet access in these major developing economies of the world.

In particular, China, with its burgeoning middle class with disposable income and a government-led campaign promoting consumerism, is set to rival the United States in terms of e-commerce spending. This growth in online shopping reflects the fact that China has the highest number of people purchasing goods online in the world.

Motivations

There is a general shift in spending from physical stores to online shopping. The motivations for changes in shopping behavior are complex and consequently difficult to address for future transportation planning. In general, e-shopping is often associated with the heightened convenience offered by shopping online. This is captured in terms of (1) the all-day everyday ability to purchase goods and services; (2) a perceived efficiency, reducing shopping time and stress; and (3) the absence of travel cost and time. Other benefits include a much wider choice that is not limited to geographic proximity to the consumer. This allows for price and quality comparisons between e-retailers. For these reasons,

personal travel and commercial vehicle operations are changing. Accessibility is no longer constrained and is not driven by travel time, distance, or travel costs as e-commerce dispenses with these elements. T. Golob and A. Regan discuss the structural changes undertaken by the freight transportation industry in response to the rapid increase in e-commerce and online purchasing activity. This includes the size of shipments, where freight is moved to, and the time frames for freight movements.

Transportation Impact

Undoubtedly, e-shopping and its growing global-market retail share changes travel behaviors, choices, trip frequencies, and carbon footprint of items and services purchased online. However, to date, there appears to be little empirical evidence providing insight into the impacts of e-shopping on travel. Researchers Orit Rotem-Mindali and Ilan Salomon suggest that online shopping is likely to reduce transport activity as telecommunications substitute the traditional physical journey made to a store. However, C2C has become popular through Internet sites such as eBay and Gumtree. This type of e-shopping can have a perverse effect on travel behavior by increasing travel trips, distances, and transport emissions in order for buy and sell transactions to be completed.

Similar to Rotem-Mindali, researchers Amalia Polydoropoulou and Andrea Papola recognize that telecommunications technologies and the Internet are likely to impact the demand for physical transportation and offer improvements in the efficiency and safety of transport systems, leading to a better environment through reduced travel and pollution, and time and material savings. This reflects earlier work done by scholar S. Cairns in 1996, which determined that e-shopping is more efficient not only in terms of vehicle miles traveled but also in reducing carbon emissions and energy use when compared to delivery based on consumer travel.

Individuals' e-shopping behavior and the effect on transport demand was considered by Polydoropoulou and Papola. Their research found that substitution of in-store shopping trips with e-shopping was prominent for specific product categories (especially grocery products). Evidence from research carried out by Cairns in 2005 in the United Kingdom and elsewhere found that substituting

car trips for van trips in grocery and other household shopping has the potential to reduce vehicle kilometers by 70 percent or more. Home delivery services for UK domestic shopping is increasingly replacing personal car travel for shopping. Polydoropoulou and Papola also concluded that the number of trips for other than shopping and work trip purposes, such as leisure trips, was not influenced by e-shopping. Results also indicated that technological improvements, such as improved online security systems and delivery options, have played a significant part in the decrease in shopping and work travel trips and the consequent rise of ICT use and e-shopping.

E-shopping can fundamentally change travel behavior. In a localized study conducted by scholar Sendy Farag and others in 2007, which explored the use of e-shopping and its impacts on personal travel behavior in the Netherlands, it was found that people living in areas with relatively many shopping opportunities buy online as often as do people who live in areas with relatively few shopping opportunities. The critical finding of this research is that the influences and demographics of e-shoppers remain undetermined.

It appears difficult, if not impossible, to identify specific characteristics associated with those choosing to shop online, and therefore the transportation response required is likewise difficult to determine with any certainty. Author Patricia Mokhtarian considers in a 2004 article analyzing causes of shopping-related changes in transportation that travel may reduce in some circumstances but in others travel may increase. Her conclusion is that there is no support that e-shopping will reduce net travel. She suggests that in the future there will be continued adoption of both store and e-shopping and that this presents formidable measurement challenges for assessing the transportation impacts of e-shopping.

It is clear that e-shopping is changing the way people conduct their lives and the way they do business. Over 2 billion people now buy groceries, electronic and electrical gadgets, clothes, travel tickets, and countless other products and services online. In some cases these purchases may be conducted in a completely virtual environment, for example, plane tickets; others may involve travel to collect an item and others will involve the delivery of that item to the online purchaser (whether that is B2C or B2B).

These all have varying impacts on transportation. The first takes items out of commercial haulage and delivery services, the second may increase personal travel both at a local level and farther afield, and the latter places demands upon the freight and haulage industries to adapt to different volumes and haulage loads, creating different haulage networks and routes.

While e-shopping is viewed as a means of reducing the number of personal travel trips and thus a corresponding improvement in road safety, it should be noted that the subsequent increase in deliveries by truck increases traffic in areas, often residential, which poses threats to pedestrian safety. For these reasons, it is clear that planning to meet future transportation needs is complicated by the inability to predict with any degree of accuracy the effects of e-commerce on travel needs.

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See Also: Information Technologies and Transportation; Telecommuting and Telecommunications; Travel by Households; Travel Demand Forecasting.

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Ethanol

Ethanol, empirical C_2H_6O and molecular CH_3CH_2OH (also known as ethyl alcohol, grain alcohol, drinking alcohol, and pure alcohol) is a volatile liquid suitable for use as a fuel. It has been used throughout history as a psychoactive drug in alcoholic beverages, fuel for lamps and heaters, an accelerant for fires, an ingredient in medicine, a component of synthesizing chemical products, and a transportation fuel. The largest use at present is as a transportation biofuel additive to gasoline for automobile engines. Ethanol can help reduce dependence on petroleum, increase octane, and reduce tailpipe pollution (including greenhouse gases from direct combustion).

Ethanol has a long history as a fuel. In 1826, U.S. inventor Samuel Morey developed an internal combustion engine that would run on ethanol and turpentine, and in 1860 German inventor Nicholas Otto fueled one of his engines with ethanol. By the 1890s, ethanol was used to fuel farm machinery in Europe. In 1896, Henry Ford built the Quadra-cycle, his first automobile, to run on pure ethanol. In 1908, he began production of the Model T. It had a flexible hybrid engine able to use gasoline, kerosene, or ethanol. Ethanol can also be used as a rocket fuel.

Ethanol can be produced directly from sugars through fermentation and distillation processes; from starches, as in maize or other grains, which must first be converted to simple sugars through a process called saccharification; from cellulose (wood, grasses, or the inedible parts of plants), which requires a greater amount of processing to produce the sugars needed for fermentation; and from ethylene, a petroleum by-product, by cracking a long chain of hydrocarbons found in crude oil at high temperatures and using a phosphoric acid or another appropriate catalyst. Bio and Petro ethanol have identical chemical formulas. Ethanol produced for fuel is usually dehydrated to increase its usable energy content per unit volume and/or to increase its ability to be mixed with gasoline or used directly as a fuel, and to reduce the risk of hydrous ethanol corrosion in vehicles. Dehydration is typically done through a single- or multistep distillation process with an additive such as benzene or by forcing the vapor through a molecular sieve.

Ethanol can be mixed with gasoline to increase the octane of the gasoline or used directly as a

fuel. It is used in standard mixtures ranging from 10 percent ethanol and 90 percent gasoline (E10) through E100 (100 percent ethanol). Engines must be designed specifically to use the ethanol mixture. Some vehicles (FFVs) use flexible fuel (flex fuel) engines, which are designed to use a range of different mixtures. Most modern (as of 2013) FFVs are optimized to use E15 to E85 fuels, though the technology exists to make engines that run on E0 to E100 and some vehicles are designed to do so.

Policies have played an important role in the use of ethanol. In the United States the unfavorable tax on camphene, a blend of kerosene and ethanol, in the late 19th century and the discovery of inexpensive oil combined to differentially encourage gasoline use in transportation. Prohibition in the United States (1920–33), which significantly reduced production of ethanol, also discouraged the use of ethanol as a fuel. The oil embargo in 1973 led to increased interest in renewable resources, including ethanol. However, it was not until the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 that ethanol production significantly accelerated in the United States, the largest consumer of transportation-related petroleum products.

Brazil, the world's second-largest producer of ethanol after the United States, is also the world's largest exporter. Brazil has considered ethanol to be an important part of its fuel sources. With the oil crisis of the mid-1970s, Brazil, wishing to ensure energy independence, instituted the Programa Nacional do Alcool (National Alcohol Program) in 1975. This provided government funding to phase out dependence on petroleum in favor of ethanol produced from sugarcane, a major national crop since 1532. Production of ethanol from sugarcane is significantly more efficient than from maize, the primary feedstock in the United States. This is primarily because sugarcane has a high sugar content and does not rely on conversion from starch to sugar.

Bioethanol is subject to vagaries in the marketplace, just as any other commodity. Poor growing seasons can cut into the availability of feedstocks, as did the decline in sugarcane production from 2009 to 2012 in Brazil. Reduced supplies and increased prices for sugar reduced the sugarcane available for ethanol feedstock and affected bioethanol availability.

Most of the energy content of plants is in the cellulose, rather than the sugars and starch. Cellulosic ethanol can be produced from the cellulose by-products of agriculture, wood chips, cheat grass, other biomass, and waste. Production of cellulosic ethanol is generally less efficient (greater energy input than energy output). However, research funded by the United States, Brazil, other countries and private industry is improving the situation. For instance, DuPont built a successful test plant in Tennessee and planned construction of an operational facility in Iowa to open in 2014. Planning is under way for several cellulosic ethanol production plants with private and government funding by others as well.

Accounting for all energy inputs (all energy to produce the feedstock, transport it, and convert it to ethanol), grain-based ethanol has a slightly better energy output than input, and sugarcane-based ethanol has a significantly greater energy output than input. If successful, the cellulosic ethanol plants will significantly increase the ethanol output from maize, sugarcane, and other feedstocks.

From a grain grower's perspective, ethanol is a viable alternative to growing grain for food because a lower quality grain can be used and less care is required for storage and transport to the ethanol production facility than for food-quality grain.

While the use of grain for ethanol has affected the availability of grain for food, there are numerous other factors that have contributed to reduced availability of grain for food and driven food prices higher during the period from 2006 through 2012. These include, on the demand side, population growth, increased demand for meat, dollar devaluation, large foreign exchange reserves, aggressive purchases by importers, importer policies, and others. On the supply side, contributing factors include slowing growth in agricultural production, rising production costs, adverse weather, and exporter policies. While ethanol from food grains is an important contributor to food price increases, it is not the only one.

There are other issues related to bioethanol. To meet growing demands for energy with bioethanol, feedstock growth will need to expand, in large part by increasing acreage dedicated to feedstock. Converting forests of any type, peatlands, savannahs, grasslands, and some crop lands to the production of biofuels will create a carbon debt by pulsing 17 to



A microbiologist with the U.S. Department of Agriculture's Agricultural Research Service performs corn-to-ethanol research with a recirculating batch jet cooker, which models the liquefaction step in the dry-milling ethanol process.

420 times the carbon dioxide into the atmosphere than the annual tailpipe reduction from use of biofuels. Those increasing greenhouse gas concentrations will take many decades to draw down.

Conclusion

Research and development of cellulosic ethanol and alternative feedstocks are likely to improve the total energy output, reduce the demand for land conversion, reduce the demand for grain for fuel, and improve the ratio of greenhouse gas emissions per unit of energy produced. However, increased use of crop residue will change their availability to be returned to the soil and may increase the need for fertilizers to maintain soil nutrients and thus increase nutrient runoff from farmlands. Bioethanol is a valuable contribution to the fuel mix. However, the ramifications of expanding its use must

be considered to ensure that negative unintended consequences are limited or eliminated.

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See Also: Air Pollution, Automobiles; Alternative Automotive Fuels; Alternative Fuels; Alternative Motor Fuels Act of 1988; Biodiesel; Biofuels; Green Fuels.

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Ethical Issues

Ethics is a discipline dealing with the set of rules, principles, and beliefs used to judge the value of human actions. Ethics are relevant in the transportation sector because of the diversity and the social relevance of its effects, both positive and negative. Normative assessments of transportation plans and policies invoked by policy makers, researchers, and activists often use concepts such as equality, equity, fairness, and justice, which are informed by ethical views. Despite the increased interest in these issues in policy debates and research, there are few examples of actual attempts to explicitly address them in transport planning.

This article presents contemporary perspectives around ethical questions in transportation,

including social understandings of accessibility, risk, and environmental effects, as well as a review of transportation project evaluation methods and the implications of ethics for policy makers, researchers, and individuals and companies making decisions in the transportation market.

Transportation's Positive Effects

The purpose of transportation is to move people or objects from one place to another. Although in theory transportation systems enhance people's physical mobility, the design of the infrastructure may fail to address the specific needs of individuals who already face limitations to their physical mobility, such as the elderly and disabled people. If one accepts the propositions that all individuals have a right to mobility and that the individuals more vulnerable to losses of mobility should be given special attention, then society has the moral responsibility to meet the needs of these individuals.

Addressing these needs presupposes the implementation of proactive strategies to remove the barriers individuals face in accessing the transportation network, such as the introduction of buses without steps or the redesign of the street network to meet the limitations of elderly or disabled pedestrians. It can also involve measures of positive discrimination at the level of spatial planning, such as the attachment of priority status to the provision of public transportation in areas with high proportions of elderly people.

A broader view would also consider factors that prevent individuals from fully realizing the mobility potential offered by the transportation system. For economic reasons, young people and low-income or unemployed individuals may have limited access to private vehicles and are more vulnerable to increases in the costs of public transportation. Social and cultural aspects add to these factors to place other groups, such as women and ethnic minorities, at a potential disadvantage in the use of the transportation system.

The disadvantage of some groups may also have a geographic dimension, if they face limitations in the access of specific destinations such as jobs, schools, and facilities such as hospitals, parks, or food shops. Research shows that the processes of suburbanization and decentralization of jobs in many cities in North America and Australia and in some European cities have in many cases created

a “spatial mismatch” between the places and residences and work of low-income groups and racial minorities. The problem is compounded by lack of access to private vehicles and, in some cases, by the relatively low levels of provision of public transport in the areas where these groups are more concentrated. In most industrialized countries, the concentration of jobs and facilities in medium-sized towns and the closure of facilities in smaller towns and villages have also led to accessibility problems in rural areas, contributing to the isolation of the population in these places.

Disadvantages in accessibility levels depend not only on public policies in the transportation and other sectors but also on the decisions of individuals and companies (including transportation providers) in the free market. However, the problem is socially and politically relevant because unfulfilled mobility may contribute to the social exclusion of some individuals. This is because transportation fails to allow individuals to participate in activities and to access goods, services, and opportunities, with potential effects on their income, education and employment prospects, health condition, levels of social interaction, and overall life satisfaction. Once one considers exclusion as a social problem, then a need arises to consider the role of transportation in solving it. Policy makers and researchers have given more attention to the relationship between transportation and social inclusion in recent years and emphasized the relevance of providing transportation and removing barriers that limit the use of the system by some groups.

The recognition of society’s moral responsibility to ensure the inclusion of all individuals can be justified with the fact that social exclusion is linked to wider problems, such as unemployment and social unrest. The problem can also be understood in terms of concepts of equity or social justice. For example, John Rawls’s theory of justice emphasizes the need for society to provide all individuals with a minimum level of a set of “primary” or essential goods, in which one can include mobility and accessibility.

The concept can also be covered by Amartya Sen’s theory of justice, which focuses on individual capabilities to use primary goods to derive welfare. In the cases where a specific group is systematically at disadvantage in many regions, across time, or as a result of several projects, the issue can also be

framed in terms of the value of nondiscrimination. In fact, in the United States, activists and grassroots movements often use the term *transportation racism* to draw attention to the failure of the transportation system to meet the needs of racial minorities.

Social differences in mobility and accessibility levels can also be understood as “goods” that are distributed by society, distribution that is partly determined by policy makers. Theories of distributive justice or equity that are often used in economics can be applied to judge the distributive outcomes of the transportation system. Although these theories tend to include a concept of equality, they are better described as justifications for departing from equality. A usual distinction is that between horizontal and vertical equity. In the case of transportation, the application of principles of horizontal equity compares the distribution of mobility and accessibility across individuals judged to be comparable, while the application of principles of vertical equity would give higher priority to the individuals judged to be at a disadvantage.

Transportation’s Negative Effects

The outcomes of planning and policies in the transportation system can also be judged in terms of the level and the distribution of their negative effects. An important effect regards the negative environmental effects on the neighborhoods crossed by transport infrastructure, especially in the sections with high traffic levels, which are associated with high levels of air pollution and noise. The exposure to these impacts poses significant health risks for the population exposed.

The issue is often discussed using the concept of environmental justice. One interpretation of this concept is that there is a universal right to a clean local environment. In fact, like mobility and accessibility, environmental quality can be assigned the “primary” good status proposed in Rawls’s theory of justice. A possible way to translate this principle into transportation policies is to focus on “socially unacceptable” levels of transport pollution and noise. Justice would then be achieved through the definition of regulations or through the allocation of resources that ensure that those levels are maintained.

Examples are zone standards for pollution concentrations in each area or emission standards for vehicles. The definition of these standards is

theoretically related to the effects of pollution on human health, but in practice, they vary across countries, showing that there are relevant contextual (often political) factors in their interpretation.

An alternative perspective on environmental justice is the identification of cases of unbalanced distribution of environmental effects. Research in a large number of cities in North America and Europe has shown that low-income and racial minority communities tend to be disproportionately exposed to these effects. Grassroots activists and environmental organizations often justify the relevance of these patterns with the principle that the social distribution of environmental quality should not be detrimental to groups that are already at disadvantage in terms of the distribution of other resources, usually income or political power. This concept has been given increased political attention and has crawled into legislation in some countries. For example, in the United States, Executive Order 12898 outlines the actions to address environmental effects of public policies on low-income groups and racial minorities. Despite these initiatives, the issue remains the subject of intensive discussion among politicians, researchers, and activists, especially regarding the question of whether rights and distributive justice should refer to individuals only or to groups of individuals defined by ethnic or socioeconomic attributes.

At a wider level, transport pollution can also undermine long-term environmental sustainability and have consequences on the welfare of future generations. Motorized transportation contributes to the emission of carbon dioxide (CO₂), which is linked to climate changes such as global warming. Most transportation modes also contribute to the depletion of nonrenewable resources such as fossil fuel, while the use of biofuels has costs of opportunity in terms of resources diverted from food production. As the negative environmental effects are shifted into the future, issues of intergenerational justice arise. An often-used principle to approach this kind of problems is that future generations are vulnerable to the actions of the current generation and so the latter are morally responsible for irreversible environmental effects affecting the former. However, this general principle leaves many open questions, such as how far into the future should one be concerned about and whether and how to consider uncertainty over future developments

that may revert current processes of environmental deterioration.

The problem becomes more complex if one considers that developed countries are currently responsible for a disproportionate proportion of greenhouse gas emissions while the most severe effects of global warming are likely to occur in developing countries, due to their geographic location in more vulnerable areas of the globe. Questions of international justice also arise in relation to current levels of pollution, as some pollutants are dispersed in the atmosphere and may cross state and country borders. Arguments of environmental justice made at the level of individuals can therefore apply when looking at countries and are often summoned in negotiations of international environmental agreements.

The transportation system also has impacts on nonhuman beings. Land and water transportation disrupts wildlife and destroys habitats, and the short-term effects of air pollution and the long-term effects of global warming also affect biodiversity. Whether these impacts are morally relevant depends on one's understanding of whether nonhuman beings have moral status and whether the assignment of this status can override considerations of human welfare.

Safety Issues

Ethical issues also come into play when addressing accident risks. Society usually imposes safety regulations concerning vehicles, passengers, and passengers' use of vehicles. These regulations address the well-being of society in general, through the minimization of the number and gravity of accidents. Some of the regulations, such as the use of seat belts, can, however, be regarded as paternalistic, as society imposes behavior to protect individuals from risks that are not shared with the rest of society, although even in this case, regulations can be justified in terms of the rationalization of emergency and public health resources.

In the context of population aging in most developed countries, another important issue is whether society should promote or restrict driving by individuals of advanced age. The resolution of this question needs to balance competing societal objectives. Elderly drivers have a higher probability than average of being involved in accidents and are more vulnerable in the case of accident. On the

other hand, the ability to drive is a crucial factor for independent mobility, life satisfaction, and overall well-being in this age group. The imposition of regulations on driving license renewal and the mandatory screening and assessment of older drivers are therefore controversial measures.

The ethical aspects of transportation safety become more relevant when accident risks are not evenly distributed across society. For example, children and the elderly tend to be more vulnerable to pedestrian accidents. The concept of “justice as care” can be applied to defend that society should give priority to the protection of individuals in these age groups. In addition, empirical research suggests that the spatial distribution of pedestrian risk is also uneven and that individuals in low-income or racial minority communities tend to be disproportionately exposed to risk, due to higher traffic levels in these communities or to higher exposure times. The moral assessment of this pattern shares the same problems as the assessment of the distribution of other positive and negative impacts of transportation, especially the question of whether the racial and socioeconomic characteristics of the victims are morally relevant or if society should focus solely on the minimization of overall risk.

Public Intervention

Governments in most countries have some type of intervention in the transportation sector. At a broad level, this intervention needs to consider a balance between different societal objectives, such as economic efficiency, social justice, and environmental sustainability. At the level of each policy, there are also trade-offs among the welfare of users and non-users of the system, among different types of users, and among different types of nonusers.

Competing ethical principles may apply in the resolution of these conflicts. These principles are not necessarily universal, as each society has different concerns at each moment in time. There are also different ways to frame the objective of social justice in public policies. For example, adopting consequential views, the achievement of justice relies on the judgment of policy outcomes, while applying procedural views of justice implies the fairness of the decision-making processes leading to the definition of policies.

Conflicts may arise in the allocation of investment in the transportation system in different regions. The

concept of territorial justice is often applied in these cases. This concept may be supported not only by economic arguments but also by the moral responsibility of governments to promote regional cohesion and correct for imbalances in variables such as economic or demographic vitality of each region, given the crucial role played by transportation investment in the determination of these variables.

Further ethical issues arise in decisions about the construction of new transportation infrastructure. The choice of investment on private versus public transportation or of motorized versus nonmotorized transportation depends not only on economic principles but also on the governments’ normative assessment on the relative merits of different types of mobility and on the priority that should be attached to the needs of different types of users. Conflicts may be resolved by promoting policies addressing multiple social objectives. For example, the provision of infrastructure for walking and cycling, such as urban trail systems, can address accessibility and environmental issues simultaneously. At the level of each project, other subjective questions are whether, how, and how much to compensate the individuals affected by the negative impacts, including expropriations and safety and environmental effects.

The policies to address accessibility problems affecting some groups or areas may also be questioned on moral grounds when they collide with other societal objectives. The provision of public transportation and transport subsidies has effects in terms of the use and distribution of public resources, depending on the way such programs are financed. The provision of bus services in areas with low demand may also clash with the objective of environmental sustainability, as buses running with few passengers are responsible for a relatively high level of pollutant emissions per passenger.

The issue is also relevant in the case of traffic policies. Measures such as road pricing and traffic restriction are often applied with the objective of reducing safety and environmental effects in the areas of concern. However, this is only achieved by limiting the mobility of car users. It can be argued that these limitations violate their right or freedom of movement. The methods used to implement certain policies such as road pricing may also be questioned regarding their intrusion on road users’ privacy. The rights of road users then clash with the rights of mobility and safety of pedestrians and

cyclists and with the rights of safety and environmental quality of the residents in the areas where traffic decreases following the application of policies. This dilemma is resolved in practice by the application of principles regulating the allocation of space among different users and the regulation of the circulation of some users in some areas.

Traffic policies also have efficiency and distributional dimensions, as they imply the use and redistribution of resources. Traffic restriction policies reduce accessibility of both individuals and freight transportation and cause congestion. In some contexts, the people at disadvantage in terms of mobility and accessibility may be disproportionately affected. Regulations on traffic speed also imply a trade-off between safety benefits and time losses. Economic methods such as taxes have further distributional implications, depending on the base on which the tax is applied (ownership or use of private vehicles, distance traveled, or level of emissions). The revenues of the system may or may not be applied to improvements of the transportation system.

Regardless of the philosophical standings used to judge the desirability of public interventions, one should consider that policy makers are not a neutral apparatus applying policies to achieve the maximum social good. Controversial policies, such as policies with important distributional effects, may not have sociopolitical feasibility. The identification of fairness in policy outcomes and decision-making processes are important factors determining people's acceptability of these policies, and the need for public participation is increasingly called upon, especially in projects that affect social exclusion. There are also questions regarding the legitimacy of applying paternalistic policies that go against society's preferences. This can be the case of anticar policies, which yield environmental benefits that may not be recognized or valued by people. It may also be the case of policies subsidizing public transportation, as they represent a choice made by public planners on the set of choices faced by individuals.

Finally, policies are designed and applied by politicians and may reflect the ideology of their political party or be influenced by influential individuals or groups, leading to biased decisions. Powerful lobbies such as car manufacturers may influence decisions on traffic restriction policies. Different levels of political mobilization among the groups sharing the benefits and costs of transportation projects

may also influence the type and characteristics of these projects. For example, road alignments and the location of railway stations may be determined by political support or protest faced by policy makers in the affected areas.

Project Assessment and Evaluation

The inclusion of explicit ethical principles in the assessment and evaluation of transportation projects is usually limited to the acknowledgment of distributional concerns. In the United States, the Transportation Equity Act for the 21st Century (TEA-21) recognizes distributional impacts as required factors to assess regional transportation plans. A range of developed countries, such as England and Japan, have also attempted to include these concerns in their national transportation evaluation frameworks. Nevertheless, little consensus exists on the integration of the necessarily abstract and subjective principles of equity into current methods of evaluation, which are based on rigorous economic principles and methods.

Cost-benefit analysis (CBA) is by far the most frequently used method to evaluate transportation projects. This method is built around the hypothesis that a project should maximize total welfare across society. At its most simple, the benefits and costs of a project or policy are given monetary values, summed, and then compared. If the aggregate benefits exceed aggregate costs, the project is identified as having social worth and, in theory, should be implemented. The rationale for this formula relies on the principle stated by economists Nicholas Kaldor and John Hicks, which states that an outcome (such as the set of effects of a transport project) is desirable if the people who are made better off are able to potentially compensate the people who are worse off and still be better off. In practice, the final decisions over the implementation of the project are political and the results of CBA are treated as an indicator of the economic efficiency of the project, which is balanced against other social objectives.

As many of the effects of transport projects and policies are intangible, the application of CBA in this field relies on a series of well-developed methods to derive their monetary values. These methods are based on economic theory and intend to capture people's preferences, measured as willingness to pay or accept marginal units of the physical units of the effects of the project (such as, for example, minutes

of travel time, percent probability of accident risk, or noise decibels). Preferences can be estimated by using surveys (stated preference methods) or by looking at the prices of goods and services related to the effects and assuming that they reveal people's preferences over these effects (for example, looking at differentials in rents or house prices to value differentials in noise levels).

Despite its widespread use, CBA suffers from several weaknesses, identified in a large number of academic studies. Part of the criticism of the method revolves around the absence of links with ethical concerns. The argument is that any evaluation method incorporates judgment values, which should be made explicit. The focus in CBA on welfare maximization and people's preference reduces the normative assessment of projects to the principle of utilitarianism developed in the 19th century by Jeremy Bentham and John Stuart Mill. Economists have more recently studied possibilities of addressing other principles of distributive justice within the framework provided by CBA, for example, by attaching weights to the effects of the project on different social groups, but the use of these methods in actual project evaluation is still limited.

The necessity of translating all effects in monetary value has also attracted a fair deal of criticism. The assignment of a value to the increase of health and environmental risks and to lives saved and lost (usually measured as "statistical lives") is a sensitive issue. In addition, willingness to pay depends not only on individual preferences but also on ability to pay and so the values assigned to the benefits and costs of a project are biased toward the preferences of individuals of higher income.

The reliance on the estimation of people's preferences may fail to address ethical concerns even when these preferences are not measured in monetary terms. Philosophers such as Jon Elster have drawn attention to the concept of "adaptive preferences," that is, preferences that are determined by context. This concept is relevant in the transportation field, as there is evidence that disadvantaged groups may not recognize their disadvantage in terms of mobility and accessibility or the degree to which they are exposed to transport pollution.

Issues of intergenerational equity are also not made explicit in CBA. Benefits and costs occurring in the future are usually discounted by calculating their net present value, but the definition of the

methods and parameters used in this procedure are far from being consensual.

In order to overcome the limitations of CBA methods to address equity concerns, alternative approaches have been developed, of which the most important is multi-criteria analysis (MCA). This method is based on the definition of a set of indicators in the assessment that are combined by a structured set of weights measuring society's preferences. The indicators are not necessarily measured in the same unit. This approach has the potential of including diverse ethical concerns in project assessment, although this may also be regarded as a weakness, given the subjectivity in the determination of weights.

The use of MCA has been growing in recent years, especially in the assessment of large-scale transport projects. The combination of CBA and MCA methods within the same evaluation framework has also produced encouraging results, such as in the case of the planning of the trans-European transport network (TEN-T).

At the level of measurement of benefits and costs, there is also growing academic research on methods that surpass the need for monetization and attempt to measure the "value of use" of effects such as mobility and accessibility. As with other approaches capturing ethical concerns, the main limitation to these methods is the high degree of subjectivity and perhaps paternalism in their application.

Ethics in Transportation Research

Ethical issues are also relevant at the level of research conducted by academics and consultants. An important aspect regards the independence and impartiality of the studies, as researchers may be influenced by the institutions commissioning projects or awarding funding. Codes of conduct are common in academic research and are especially important in the case of transportation research. Transportation projects are expensive infrastructures with large and far-reaching effects. The resolution of dilemmas over the redistribution of resources and welfare linked to these projects is informed by the results of research. Therefore, a degree of moral responsibility for the consequences of the project lies with researchers, who may face personal dilemmas over which methods to use and which results to report. The common good, the interests of the commissioners of the

research project, and the researchers' own ethical views may differ.

The role of ethics comes into play at the stages of both data collection and analysis. This may involve the decisions regarding the object of analysis, for example, individuals at risk of social exclusion tend to be underrepresented in surveys and interviews. Ethical presuppositions are also unavoidable in the choices of the scenarios studied and the variables used in the assessments of benefits and costs, as researchers may feel pressured to obtain and report optimistic results. This may lead to biased estimates for the project's demand or to a discrepancy between forecasts and actual costs. The selection of which external costs to include in the analysis and of the methods to measure the level and distribution of those costs are also subjective decisions. The models generally used in transportation research also have implicit assumptions, as they tend to be based on economic theory and rely on quantitative data, which may prevent the analysis of intangible costs and questions of social justice.

Ethical Aspects of Individual Behavior

While ethical considerations are relevant for policy makers and researchers judging the social worth of transport projects and policies, they may also inform the preferences and choices of individuals and companies making decisions in the transportation market.

Ethical motivations are especially relevant in decisions over modal choice, such as the use of public transit (versus private vehicle) and land transport (versus air transport). These decisions may be partially based on altruistic or environmental reasons. These reasons may also be applied in decisions over the type of vehicle owned (such as the choice of electric cars). Individuals may also choose to reduce the number of trips or the distance traveled (for example, in commuting to work). There is still little quantitative research, however, on the role of these types of motivations in people's willingness to pay for improvements in the social and environmental aspects of transportation policies.

On the supply side, the process of deregulation of the transportation sector in many countries raises questions regarding the social responsibilities of companies in the private transportation sector. Critics of these processes often point to the fact that private companies cannot attend to these issues to

the same degree that organizations in the public sector do, as this can compromise their commercial viability. The survival of these companies may be incompatible with some of society's objectives. For example, the level of the fares that maximizes economic efficiency may exclude some users from the system. Private operators also do not have the incentive to serve areas with small demand, such as rural areas, dispersed suburban areas, and areas with high rates of car ownership, while car manufacturers do not have the incentive to reduce the environmental impact of their products. Employment issues are also relevant as women and racial minorities tend to be underrepresented in managerial positions and in certain professions in companies in the transportation sector.

Some sectors in the industry face particularly complex ethical challenges. Aviation is one of the human activities with a higher share of responsibility for the emission of greenhouse gases and has a substantial impact on the local environment in areas around airports. As such, the consequences of the growth of aviation companies, including the increase in air traffic and the construction or expansion of airports, are always subject to much public discussion. Safety is also a crucial aspect in air transportation, and public authorities and companies in the industry usually impose strict regulations and codes of conduct to minimize risk.

Companies in the freight transportation industry also face specific moral issues. The globalization of channels of production and distribution of goods has increased the environmental impact of the transportation of goods, contributing to the depletion of natural resources and climate change. There is no consensus on whether freight transport companies are morally responsible for these effects, as they depend on national and international regulations and, ultimately, on the demand for and supply of the products carried. The transportation of some goods, such as hazardous materials, also involves public health risks. Decisions involving the routes taken in their transport are politically sensitive, and activists have often claimed that these routes tend to cross low-income and ethnic communities.

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See Also: Benefit–Cost Analysis of Transportation; Environmental Justice; Multiple Criteria Decision Making/Aiding; Social Equity and Discrimination in Transportation; Transportation and the Disadvantaged.

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ameliorating these problems is the principal concern of evacuation planning. The resulting evacuation plan describes aspects and contingencies in the evacuation process under the broad goal of moving people out of the threat area in the least amount of time and with the least amount of risk.

Evacuation is generally divided into six overlapping time phases: incident detection time, decision time, notification time, preparation time, travel time, and verification time. Incident detection time is the time it takes officials to detect that an event has occurred. In the case of a hurricane, this might be done via satellite days prior to landfall, but the challenge of detecting the release of an odorless, invisible toxic gas from a storage site would be much greater. Decision time is the time it takes officials to determine whether to recommend protective actions to the public. Notification time is the time it takes to communicate a warning message to the public through radio, television, the Internet, or other media. Preparation time is the time it takes the public to gather family members, pets, and valuables prior to departing. Travel time is the time it takes evacuees to move from an origin in the threat area to a safer destination. Verification time is the time it takes officials to determine whether everyone has left the threat area.

Each of these time phases can alternatively be viewed as a series of questions for evacuation planning purposes. The principal question in the incident detection phase is this: how will an event be detected and monitored in a timely manner? The answer to this question might be by remote (hurricane) or in situ sensors (tsunami), whereas in the case of a wildfire or sudden hazardous material (hazmat) highway spill, the plan might be to rely on eyewitnesses with cell phones. Three important questions that need to be answered in the decision-time phase include who needs to take action, what is the best action, and when do they need to take it?

The answers to these questions comprise the basics for an official warning message. The primary planning question in the preparation phase is how can one best prepare the public such that their response to a future evacuation recommendation is likely and timely? The travel-time phase is where the most significant transportation questions arise, including what are the likely origin-destination flows, travel modes, routing, and roadway control? The question in the verification phase is how will officials

Evacuation Planning

Events ranging from hurricanes to hazardous material spills represent environmental threats to people and property. Evacuation is the process of moving at-risk populations to safety by relocating them outside a defined threat area. As evacuation is primarily about human movement, it has substantial behavioral and transportation dimensions. Evacuation planning is the process of anticipating how to best move people to safety should a disaster occur. There are many problems that can arise in an evacuation that serve to delay or prevent officials from evacuating everyone quickly, and anticipating and



A hurricane evacuation route leads drivers to safety in Corpus Christi, Texas, three days before Hurricane Ike makes landfall, September 10, 2008. Some people failed to heed evacuation warnings, which contributed to the 84 deaths caused by Ike.

determine who has evacuated, who has not, and what should the at-risk population that is not clear of the threat area do (for example, shelter-in-refuge)?

The principal behavioral goals in evacuation planning are (1) to communicate the warning message to the most at-risk people possible and (2) to achieve the highest compliance level—the percentage of people who adopt the recommended action. The most powerful behavioral tool in an emergency manager's toolkit is a well-crafted warning message that includes unambiguous instructions regarding who needs to take action, what action they should take, and why they should take it.

Furthermore, a wealth of research has repeatedly shown that warning people is a social process, that is, people need to confirm the warning with family, friends, and coworkers. In the best case, the at-risk population will be able to easily combine environmental cues (for example, smoke, flame, wind) with a well-crafted warning message received from multiple sources and subsequently confirm this with family and friends to make the decision to evacuate in a timely manner.

The concern on the transportation side of evacuation planning is moving the people that wish to evacuate to safety in the least amount of time (that is, minimizing the travel-time phase). This can involve many facets, including routing instructions, departure time staging, contraflow operations, intersection control, and public transport. Evacuation routing can be done at a variety of scales from recommending major highways as primary exits or as fine as the traffic lane-level in urban evacuations (that is, recommending the precise lanes that each neighborhood in the evacuation zone should use).

Departure staging is the process of reducing traffic congestion by subdividing the threat area into smaller, manageable areas, each of which is then assigned a particular time window within which to depart. Contraflow operations refer to the process of reversing roads or lanes to increase the road capacity away from the threat area. Critical intersections can also be reconfigured to take advantage of the fact that vehicle flows have directionality in an evacuation (that is, away from the threat area). In cases where private vehicle ownership is low, public transport options may aid in moving people out of the threat area.

As large-scale evacuation drills are generally infeasible in evacuation planning, analysts rely on computational models to run “what if?” scenarios. This process involves gathering geographic data on the anticipated threat area surroundings, including the whereabouts and attributes of the population, roads, and potential shelters. Relevant attributes of the population include demographics, vehicle ownership, and socioeconomic level. Important roadway attributes might include the number of lanes, directionality, and vehicle capacity. Potential shelter locations and associated capacity can also be helpful information.

Evacuation models generally have a behavioral component that allows an analyst to vary the assumptions regarding who will respond to a warning message, how soon they will evacuate, how many vehicles they will utilize, and what routes they will likely take. A second model component represents the traffic flow process with the goal of testing how well the surrounding road network may perform under the added stress of evacuation travel demand (that is, over normal traffic flow patterns).

The results of this exercise provide a realistic range of evacuation-time estimates (ETEs) for a threat area, along with potential traffic bottlenecks and the most effective strategies for assuaging these bottlenecks (for example, departure staging, contraflow operations, intersection control).

Evacuation planning is a very vibrant research and practice area, and current topics include the role of social media in evacuation decision making, using locationally aware devices to provide precise protective-action recommendations to threatened subpopulations (that is, geotargeting), designing geosensors to detect likely threat events, providing public transport options for carless populations, and designating in-place shelter options that can avoid the need to evacuate.

Finally, regardless of how effective evacuation planning, modeling, and associated exercises can be, many evacuation decisions in actual disaster events are improvised on-the-fly. Nonetheless, it is very worthwhile to discuss likely threat events and the associated evacuation procedures that might take place, as well as to formalize the outcome of this process in an evacuation (or protective) plan.

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See Also: Emergency Response Systems; Emergency Transportation Planning and Operations; Ferries; Helicopters, Emergency Response and Law Enforcement; Transit Safety; Transportation Planning.

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Executive Order 12898

Executive Order 12898 is a federal policy intended to address threats to environmental justice in the United States. According to the U.S. Environmental Protection Agency (EPA), environmental justice is "the fair treatment and meaningful involvement of all people regardless of race, color, sex, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." Transportation agencies must integrate Executive Order 12898 into local planning practices in two primary ways: (1) assessing and addressing potential environmental justice impacts of transportation projects and (2) conducting public involvement in a way that considers environmental justice. The EPA and the U.S. Department of Transportation (USDOT) offer much technical guidance to this end, in that many complementary federal and local policies facilitate the implementation of Executive Order 12898.

Overview

In 1994, President William Clinton issued Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. Executive Order 12898 draws attention to environmental and human health effects of federal actions on minority and low-income populations. It calls on federal agencies to make environmental justice part of their mission, assessing and addressing it under each major program, policy, and activity. Executive Order 12898 does not create a process for judicial review to measure compliance:

[It is] intended only to improve the internal management of the executive branch and is not intended to, nor does it create any right, benefit, or trust responsibility, substantive or procedural, enforceable at law or equity by a party against the United States, its agencies, its officers, or any person.

In 2011, President Barack Obama issued a Memorandum of Understanding (MOU) on Environmental Justice and Executive Order 12898. The MOU signified renewed attention to formalizing the commitment of federal agencies to environmental justice. It called upon major federal agencies

to each draft an environmental justice strategy, including goals for partnering with other federal agencies to address environmental justice issues. The MOU added areas of focus not explicitly outlined in its predecessor, Executive Order 12898, such as climate change adaptation and commercial transportation. Notably, the MOU highlighted the role of the National Environmental Policy Act and Title VI of the Civil Rights Act of 1964 as policies that concurrently seek environmental justice.

In recognition of the 20th anniversary of Executive Order 12898, as the nation's lead environmental agency, the EPA put forth Plan EJ 2014 in July 2010. As the EPA emphasized, Plan EJ 2014 is not a rule or regulation but a strategy for integrating Executive Order 12898 into the agency's daily activities through cross-agency focus areas, tool development, and program initiatives. Plan EJ 2014 attempts to strategize around five cross-agency focus areas: incorporating environmental justice into rulemaking, considering environmental justice in permitting, advancing environmental justice through compliance and enforcement, supporting community-based action programs on environmental justice, and fostering administration-wide action on environmental justice.

Two key groups have guided overall execution of Executive Order 12898 and the MOU on Environmental Justice and Executive Order 12898: the Federal Interagency Working Group (IWG) on Environmental Justice and the National Environmental Justice Advisory Council. The IWG met for many years in the early mid-1990s, and heads of 17 agencies and the White House offices signed on to the 2011 MOU to renew this group. The administrator of the EPA convenes the IWG, a group comprising representatives from the Departments of Agriculture, Commerce, Defense, Education, Energy, Health and Human Services, Homeland Security, Housing and Urban Development, Interior, Justice, Labor, State, Transportation, and Veteran's Affairs, as well as the General Services Administration, Small Business Administration, and the White House offices.

To codify their efforts, the MOU on Environmental Justice and Executive Order 12898 required that the IWG adopt a charter that outlines membership, meeting expectations, and coordination of committees, including three permanent standing committees: the Public Participation Committee, the Strategy and Implementation Progress Report

Committee, and the Title VI Civil Rights Act of 1964 Committee. Also, since 1993, the National Environmental Justice Advisory Council, a group of approximately 25 stakeholders representing academia, community groups, industry, tribal groups, nongovernment organizations, and local governments across the United States, has guided implementation of Executive Order 12898.

The U.S. Department of Transportation

To carry out Executive Order 12898, the USDOT issued an agency-wide Order to Address Environmental Justice in Minority Populations and Low-Income Populations (USDOT Environmental Justice Order) in 2012 (6640.23a), an updated replacement of the 1998 version of this order (6640.23). The 2012 USDOT Environmental Justice Order outlines the process that the office of the secretary and each operating administration must use to integrate the goals of Executive Order 12898 into existing programs, policies, and activities to make assessment of environmental justice common practice. Similar to Executive Order 12898, it states that disproportionately adverse environmental health impacts on minority or low-income populations should be avoided during transportation planning, unless such actions lead to substantial harmful impacts on other valued social, economic, or environmental resources. Also akin to Executive Order 12898, subsequent USDOT orders are not upheld by judicial review or law for compliance and act, rather, as guidance policy.

The USDOT Environmental Justice Order also explains how Executive Order 12898 should be reinforced through existing policies, including the National Environmental Policy Act (NEPA), Title VI of the Civil Rights Act of 1964 (Title VI), the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (URA), major federal transportation bills, and other USDOT policies. For instance, the Council on Environmental Quality guides agencies and consultants conducting NEPA analyses on how to integrate environmental justice considerations into compulsory steps during the development of major, federally funded transportation infrastructure: scoping, environmental assessment, alternatives analysis, determination of mitigation strategies, public commenting, and decision making.

Further, Title VI states that federal agencies must ensure that no person is discriminated against on

the basis of race, color, or national origin, under any federally supported program (for example, Transportation Alternatives Program) or infrastructure development from site scoping to post-construction maintenance. Additionally, the URA ensures that displaced property owners, such as those in the footprint of a proposed transportation development, are treated “fairly, consistently, and equitably” in the process of property acquisition that may occur to prepare for a new or expanded highway, bridge, or public transit center.

Implementation

The USDOT undertakes a variety of strategies to implement Executive Order 12898 and the USDOT Environmental Justice Order across operating administrations (for example, Federal Aviation Administration or Federal Transit Administration) and through interagency efforts. The Federal Highway Administration, for instance, ensures that policy documents reflect Order 6640.23a, disseminates environmental justice guidance and research to assist transportation planners, conducts related trainings and Webinars across the country, and coordinates professional development to improve implementation of the USDOT Environmental Justice Order. The USDOT also engages in interagency efforts, including involvement in the EJ IWG’s various subcommittees and Partnership for Sustainable Communities, a collaboration between the USDOT, EPA, and Department of Housing and Urban Development.

Locally, implementation of these environmental justice policies requires the work of state transportation departments, metropolitan planning organizations, transit providers, other transportation providers, and the public. The USDOT highlights these local examples on its Web site, providing successful case studies of planning initiatives, right-of-way developments, environmental assessment procedures, and public involvement efforts that appropriately assess and address environmental justice.

The EPA and USDOT provide technical guidance to agencies and consultants doing this work. Yet, much variation remains across the nation in the implementation of the USDOT Environmental Justice Order, for instance, in selection of geographic scope and specific methods, as well as public involvement and decision-making processes.

Data collection and analysis is necessary to assess implementation of Executive Order 12898 and the USDOT Environmental Justice Order, often in the context of a specific freight or transit project. In communities hosting existing or proposed transportation infrastructure, transportation planners rely on a range of methods and frameworks to conduct these assessments, such as mapping analyses, field visits, business/housing replacement studies, community leader interviews, surveys, oral histories, and community impact assessments. This may entail close examination of secondary data, such as the U.S. Census Bureau’s American Community Survey or the Office of Highway Policy Information’s National Household Travel Survey, to study demographic, health, economic, and transportation patterns. For federally funded projects, these assessments are typically coupled with extensive environmental assessments mandated by NEPA, often including projections for air, noise, and water pollution. The USDOT Environmental Justice Order requires that the USDOT maintain information on the race, color, national origin, and income level of persons negatively affected by USDOT programs, policies, and activities.

Executive Order 12898 and the USDOT Environmental Justice Order also outline expectations regarding public involvement. Public involvement may address environmental justice issues by increasing opportunities for information sharing, public commenting or forums, and dialogue between residents, organizational leaders, and decision makers during transportation deliberations. The USDOT Environmental Justice Order specifically requires that public involvement procedures include members of minority and low-income populations who may be disproportionately burdened by a transportation project. Executive Order 12898 and the USDOT Environmental Justice Order also complement and reinforce a variety of federal policies that include guidance on public involvement. For instance, the Safe, Accountable, Flexible, Efficient Transportation Efficiency Act of 2005 specifically applied NEPA public involvement requirements to transportation planning.

NEPA now requires public comment periods during environmental assessment for federally funded transportation projects. In another example, Executive Order 13166 of 2001 orders that federally conducted programs and activities be accessible to persons with

limited English proficiency. To meet this mandate, transportation planners often print outreach materials and environmental assessment documents in Spanish or other locally appropriate languages.

Related Agency Definitions

Executive Order 12898 and the USDOT Environmental Justice Order use the following terms and definitions: Low-income means a person whose median household income is at or below the Department of Health and Human Services poverty guidelines. A minority is a person who fits any of the following criteria:

1. *Black*. A person having origins in any of the black racial groups of Africa.
2. *Hispanic or Latino*. A person of Mexican, Puerto Rican, Cuban, Central or South American, or other Spanish culture or origin, regardless of race.
3. *Asian American*. A person having origins in any of the original peoples of the Far East, southeast Asia, or the Indian subcontinent.
4. *American Indian and Alaskan Native*. A person having origins in any of the original people of North America, South America (including Central America), and who maintains cultural identification through tribal affiliation or community recognition.
5. *Native Hawai'ian and other Pacific Islander*. People having origins in any of the original peoples of Hawai'i, Guam, Samoa, or other Pacific Islands.

Adverse effects means the totality of significant individual or cumulative human health or environmental effects, including interrelated social and economic effects, which may include, but are not limited to, the following: bodily impairment, infirmity, illness or death; air, noise, and water pollution and soil contamination; destruction or disruption of human-made or natural resources; destruction or diminution of aesthetic values; destruction or disruption of community cohesion or a community's economic vitality; destruction or disruption of the availability of public and private facilities and services; vibration; adverse employment effects; displacement of persons, businesses, farms, or nonprofit organizations; increased traffic

congestion, isolation, exclusion or separation of minority or low-income individuals within a given community or from the broader community; and the denial of, reduction in, or significant delay in the receipt of, benefits of USDOT programs, policies, or activities.

Disproportionately high and adverse effect on minority and low-income populations means an adverse effect that (1) is predominately borne by a minority population and/or a low-income population, or (2) will be suffered by the minority population and/or low-income population and is appreciably more severe or greater in magnitude than the adverse effect that will be suffered by the nonminority population and/or non-low-income population.

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See Also: Environmental Justice; National Environmental Policy Act; Public Participation in Transportation Planning; Social Equity and Discrimination in Transportation; Transportation and the Disadvantaged.

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Federal Aid Highway Program

The Federal Aid Highway Program (FAHP) traces its roots to the Federal Aid Road Act of 1916, which defined the federal-state cooperative approach that underpins the country's highway infrastructure. The Federal Aid Highway Act of 1956 cemented this relationship and launched the modern FAHP, which has been continued or renewed through the multiyear authorization acts. In addition, since 1978, Congress has passed highway legislation as part of more comprehensive, multiyear surface transportation acts. Starting with the 1962 Federal Aid Highway Act, the FAHP has evolved from a primary focus on building the interstate system to a more complex, multimodal program that today funds a variety of functions related to surface transportation as new programs and areas of concern have been added to the FAHP.

The FAHP is an umbrella term referring to activities administered by the Federal Highway Administration (FHWA) but in cooperation with and administered by the states and their localities. Several components make up the FAHP, comprising separately funded categories of activities such as the Interstate Maintenance Program, Surface Transportation Program, Bridge Program, and Congestion Mitigation and Air Quality Improvement Program. Noncapital costs include routine

maintenance (those activities required to keep the highway open for public travel), administration, law enforcement, and debt service.

Historically, the FAHP (and the associated federal-aid funding) has been focused on capital construction activities, most prominently the interstate construction program. While some funding could be used for resurfacing, rehabilitation, or restoration (3R), the emphasis was on new or major reconstruction efforts. With construction of the interstate system essentially complete, and recognition that resources at all levels of government are shrinking, the federal emphasis has shifted to include 3R, preventive maintenance, and management/operations efforts. However, most costs for nonconstruction or noncapital activities are still the responsibility of state and local governments.

The FAHP has three main characteristics: (1) funds are apportioned to the states according to a legislated formula with state transportation agencies having responsibility for implementation of FAHP projects, (2) the states are required to provide matching funds (the current federal share is 90 percent for interstate projects and 80 percent for noninterstate system road projects), and (3) federal funds can generally be spent only on designated federal-aid highways.

History and Evolution of Legislation

The Federal Aid Road Act of 1916 appropriated federal funds for the construction of rural post roads

and for roads and trails within national forests. It also established basic policy for the development of main roads serving federally owned lands, reservations, or areas. In addition, this legislation initiated the advance funding approach fundamental to the FAHP. Congress appropriated \$5 million for fiscal year 1917, with annual \$5 million increases up to a maximum of \$25 million by 1921. This long-term commitment and advance appropriation allowed the states to plan ahead and build a more structured and orderly highway program. This legislation also established the federal–state partnership approach to the FAHP by (1) making state participation permissible provided that the state complies with the legislation’s provisions, (2) clarifying that the authority and responsibility of initiating projects was reserved for the states and that federal participation was dependent upon approval by federal authority, and (3) stipulating that the state highway department or its equivalent would represent the state in its administration of the program.

The Federal Aid Highway Act of 1921 divided highways into two categories: primary (interstate) and secondary (intercounty). It also gave limited federal aid to a system of highways to be designated by each state, not to exceed 7 percent of the state’s total mileage. This legislation stated that each state would be responsible for maintaining the highways constructed with federal funds. Failure to meet this requirement would result in direct federal supervision of this work, using funds that would otherwise be available to that state for new construction.

The Federal Aid Highway Act of 1944 extended the FAHP by designating a National System of Interstate Highways. This legislation appropriated \$225 million for primary roads, \$150 million for secondary and feeder roads, and \$125 million for urban federal-aid highway construction, annually. More importantly, the legislation established apportionment formulas for federal funding to be received by each state. However, no funds were authorized or appropriated for the interstate highway system. The Federal Aid Highway Act of 1952 was the first legislation to provide funds specifically for interstate highway construction, authorizing \$25 million for the interstate system on a 50 percent federal–50 percent state matching (50–50) basis.

The Federal Aid Highway Act of 1956 dramatically increased federal aid for highways. This legislation established the current Interstate Highway System

and created the Highway Trust Fund (HTF) as the mechanism to finance it. Funding for interstate projects was on a 90–10 federal–state basis, compared to the 50–50 match that previously existed (and remained for all other noninterstate projects).

Postwar Era

The postwar era witnessed steady growth in the size and number of suburbs around major cities, as people moved outward from urban hubs and automobile use grew apace. The 1962 Federal Aid Highway Act responded to the multiple effects of suburbanization by mandating urban transportation planning that was continuing, comprehensive, and cooperative (3C planning). Thus, in order to gain approval of a federal-aid highway project, states and localities, working together, had to construct an area-wide, comprehensive plan. The act stipulated that these plans were required to consider impacts on mass transit and land use along with the locations for new highway facilities. The act also addressed the need to assist those displaced by highway construction.

The subsequent Federal Aid Highway Act of 1968 expanded the Interstate Highway System by 1,500 miles and applied the Davis-Bacon Act to federally funded highway construction projects. The latter increased the cost of highway projects by mandating that public works projects pay the prevailing wage in a given locality. The 1966 act also increased flexibility in the use of interstate funds by allowing fund transfers from nonessential interstate routes to other interstate routes. Finally, the act incorporated several provisions to protect the environment by reducing some of the negative effects of highway construction. For instance, it applied the requirements of Section 4(f) of the Department of Transportation Act of 1966 to highway projects. Section 4(f) protects publicly owned parks or land designated or administered as a public park. It also protects publicly owned recreation areas and wildlife and waterfowl refuges. In regard to historic properties, it protects both privately and publicly owned properties either on or eligible for the National Register of Historic Places.

1970s and Beyond

The Federal Aid Highway Act of 1970 increased the federal share for noninterstate projects from 50–50 to 70–30 and created the Special Bridge Replacement

Program (SBRP) under the FAHP umbrella with a federal share of up to 75 percent. This legislation also created a minimum apportionment guarantee for each state for its respective highway funding.

Subsequent legislation diverged from a primary focus on funding for highways toward a much more multifaceted role for the federal government in transportation and highway policy. The Federal Aid Highway Act of 1973 authorized funds to complete the Interstate Highway System, officially named the National System of Interstate and Defense Highways. Reflecting a turn to multimodal transportation policy, this legislation also funded construction of bus lanes and highway traffic control devices and included, for the first time, provisions allowing use of federal funds for the construction of bicycle lanes, bicycle facilities, pedestrian walkways, and fixed-rail transit facilities.

The 1976 Federal Aid Highway Act established the 3R program, which, for the first time, allowed federal funds to be used for resurfacing, restoration, and rehabilitation of existing highways with a 90–10 match for interstates and a 75–25 match for other roads and highways. The Surface Transportation Assistance Act of 1982 provided for major increases in funding for bridge replacement and rehabilitation. This legislation also addressed the donor–recipient debate that existed with regard to the FAHP by creating an equity adjustment mechanism that assured each state would receive no less than 85 percent of its fuel tax and other contributions to the HTF.

By the late 1980s, the interstate system was largely completed. The Intermodal Surface Transportation and Equity Act (ISTEA) of 1991, the first postinterstate legislation, designated the National Highway System (NHS) as the only federal-aid highway system. The NHS included the interstate system and other routes that carry a large portion of the nation's highway travel. It also includes facilities that serve strategic priorities and that connect to major military installations, border crossings, airports, ports, and rail-highway transfer.

ISTEA also established the Surface Transportation Program within the FAHP, which allowed spending on projects that had previously been considered below the federal level of responsibility. These included construction, reconstruction, rehabilitation, and operational improvements for highway and bridges, bike transportation, pedestrian

walkways, and transportation enhancements to the federal-aid system. The 1998 Transportation Equity Act for the 21st Century (TEA-21) enacted a minimum guarantee for state funding of at least 90.5 percent of each state's contribution to the HTF. The Safe, Accountable, Flexible, Efficient, Transportation Equity Act: A Legacy for Users (SAFETEA-LU) Act of 2005 extended the FAHP authorization while broadening the states' ability to toll interstate highways and to operate high occupancy lanes on federally funded highways. Under the 2012 Moving Ahead for Progress in the 21st Century (MAP-21) Act, 92 percent of FAHP funding is distributed on a formula basis (through five core programs) whereby each state's share is based on a calculation set out in the law. The remaining funds, distributed through discretionary programs, are administered more directly by FHWA but with some formulaic determinations.

Structure and Funding

The FAHP is jointly administered and funded by the federal and state governments. With few exceptions, FHWA does not provide full funding for any FAHP project. Each funding category has an established funding ratio that defines the federal share of the project cost. The remaining funding comes from the state or localities. The federal–state partnership is the basic element of the FAHP. To be eligible for federal-aid funding, a state must have a state transportation agency capable of fulfilling the duties and requirements established by federal legislation. The FHWA provides funding, guidance, and technical assistance to the state transportation agency, and localities may receive federal funding through their respective states. However, the state remains responsible for ensuring all federal requirements are met for these local projects.

The FAHP does not require the passage of an appropriations bill before projects can be approved. The FHWA, through periodic authorization legislation, receives contract authority over monies in the HTF, which allows obligation of funds in advance of appropriations. The use of contract authority gives the states advance notice of the size of the FAHP (and associated funding) at the time an authorization act is enacted and eliminates the uncertainty contained in the authorization-appropriation sequence.

The FAHP is a reimbursable program, not a “cash up-front” program. When authorized amounts are

distributed to the states, no cash is actually disbursed. Instead, states are notified that federal funds are available for their use and that they can incur financial obligations, begin projects, and receive reimbursements for costs incurred. Depending on the type of project, the time elapsing from obligation to reimbursement can vary from a few days to several years.

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See Also: Federal Aid Road Act of 1916; Federal Highway Act of 1921; Highway Trust Fund; Transportation Policies, North American.

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provisions established long-lasting precedents that were reenacted time and again as central features of subsequent federal transportation acts over the next century.

There was no systematic federal or state involvement in road building in the United States until the closing years of the 19th century. Up until then, the only nonlocal road-building efforts were privately operated turnpikes financed by tolls—all of which had long since gone bankrupt and been turned over to local governments and allowed to disintegrate. Starting in the 1890s, however, intercity roads were gradually recast as a public endeavor, managed by newly created government bureaucracies. Furthermore, drivers were no longer expected to pay for the costs of the newly constructed roads. This reconception of roads and highways, from commodity to free-of-charge public good, was ultimately institutionalized by the passage of the Federal Aid Road Act of 1916.

The Good Roads movement was started by bicyclists in the 1880s and gained momentum when a leading bicycle manufacturer, Albert Pope, decided to pay the expenses of the League of American Wheelmen. He not only wanted to spread the word about the benefits of his product, he also wanted to harness the mass-politics power of bicycle owners to push for more and better roads, which would in turn make his product more practically usable. This business development strategy, started in the bicycle industry, was subsequently adopted by the nascent automobile industry. By the turn of the century, the newly formed Automobile Association of America (AAA), with the financial backing of automobile manufacturers, replaced the wheelmen as the driving force behind the movement.

Organizations that represented rural Americans also favored public funding of roads, arguing that their constituents should have access to the same modern amenities as urban residents. Cities had started the process of gradually paving urban streets and installing modern drainage systems, providing easier access for urbanites and facilitating to-the-door mail delivery many times a day, while roads in the countryside were still muddy, uneven, and unimproved, leaving residents frequently stranded, with only difficult and intermittent access to markets, information, and mail—which typically required a special trip to town to pick up at the post office, rather than home delivery. To support

Federal Aid Road Act of 1916

The Federal Aid Road Act of 1916 firmly established the contours of U.S. highway policy for generations to come. It was politically advanced by a newly assembled coalition of professional technocrats and business interests that grew out of the Good Roads movement and eventually came to be known as the highway lobby. The 1916 act was based on earlier policy experiments that had been carried out at both the state and federal levels, and its core

farm-to-market access and to expand Rural Free Delivery of mail, the Populist Party included a plank in its platform calling for publicly funded rural roads, and the Grange lent its support as well. This rural emphasis of the Good Roads movement, the desire to close the amenity differential between rural and urban, was reflected in the federal legislation that was later enacted, including the 1916 act.

Origins

The 1916 act was not, as is often said, the first federal highway aid program. It was at least partially based on pilot programs that had been enacted earlier, as well as on road-aid programs that had been developed and implemented in some of the states as the movement gained momentum at the beginning of the 20th century. The AAA cosponsored the Second National Roads Convention in Cleveland in 1909, along with the National Grange, the National Association of Automobile Manufacturers, and the American Road Makers Association, which represented civic engineers, highway contractors, and makers of road-building machinery. One year later, in 1910, Logan Waller Page—a federal official—assembled a new umbrella highway lobby organization called the American Association for Highway Improvement to coordinate all these groups. In 1911, Page convened all of these groups for the American Road Congress, a nationwide meeting to devise a coordinated political strategy. President William Howard Taft was the keynote speaker, and within a few months the federal government had enacted an experimental grant to pay for road building.

In 1912, legislation provided funds for the Post Office to pay for one-third of the costs of new rural post roads. This new program would be supervised by Page's agency, which had started as the Office of Road Inquiry and was repeatedly renamed before settling on the name Bureau of Public Roads. This relatively modest program, which authorized \$500,000 in federal aid, had itself been a compromise measure that followed the failure of a much different bill that had been proposed by a congressional Committee on Federal Aid in the Construction of Post Roads. The committee had held hearings, conducted surveys, and researched the road-aid practices of all the states, as well as of many other countries. Their proposal would have authorized the issuance of \$1 billion in 50-year federal bonds, the proceeds from which would be lent

to the states for rural highway construction. This "aid" would have been repaid by the states, so there would have been no net funding contribution by the federal government. The funding model in the successful version of the bill resembled more closely the direct-aid measures recommended by the 1911 Road Congress.

Rural Versus Urban

Though it had taken decades for road-aid advocates to secure federal legislation, success at the state level had come faster. New Jersey had enacted a State Aid Act in 1891, which offered counties grants for one-third of the costs of new roads. When lawmakers in Massachusetts tried to enact a similar law, they added the provision that the new routes must connect to towns and villages, but that aid could not be used for construction of the portions within urban boundaries. Within a decade of New Jersey's first step, seven states had similar programs in place, with more getting in on the game each year thereafter. The antiurban slant of the technical provisions continued to get stronger and more specific. The 1913 legislation enacted by Maine banned the expenditure of any of the aid within a municipality with population over 2,500, and also required a minimum project length of 7 miles. This specific population-size limit would be repeated in the 1916 federal act.

At the federal level, there was no direct road aid authorized until the 1912 law, but there had been federal legislation that provided for research and technical support. During this period, federally funded highway engineers mounted public education campaigns, put together road surveys, spoke with the press and at public events, provided model constitutions for road advocacy groups, and lent their stamp of apolitical expertise to the cause. They framed the public discussion as a set of narrowly conceived technical concerns, setting aside the essential question of who should pay for the new road-building programs. For the time being, the amount of money involved in these programs was relatively modest, and it was easy to disregard this question. Instead, the attention was focused on the need for more and better roads and the need for solutions to be coordinated by well-trained experts. Despite this air of apolitical expertise, programmatic biases were institutionalized that had long-lasting political repercussions, including tight

control of design and routing decisions by federal bureaucrats and funding formulae that steeply favored rural areas and penalized urban regions.

For example, the exclusion of urban roads and streets from these early experimental government road-aid laws seemed, on the surface, to make the modest grant programs more efficient, funding more road-miles by avoiding the most expensive projects. Engineers estimated at the time that each mile of urban highway cost about three times as much as a mile of rural highway. But, because the urban road would have been used so much more, the cost per vehicle-mile would have been much higher on the rural routes. Urban roads were still needed and would have to be built without the same generous national support afforded to roads outside cities.

The 1916 act inherited the explicit rural post road emphasis from the 1912 federal law; it inherited Maine's prohibition on spending within urban areas with population over 2,500 (unless houses were more than 200 feet apart), it inherited the Massachusetts provision that required cities to pay for their portion of intercity routes, and it added new antiurban provisions, beyond these other precedents. It capped grants at \$10,000 per mile, further shortchanging routes that required more lanes or with more complicated routing issues.

The eventual institutionalization of this antiurban perspective by the 1916 act and its subsequent persistence had the long-term effect of collecting billions in tax revenues in urban areas and spending them to develop rural transport infrastructure, simultaneously inhibiting sustained economic prosperity within cities and subsidizing economic development in areas that had previously been sparsely settled.

Regional and Interregional Highways

Not all of the road-building experiments that led up to the passage of the 1916 act had been as centrally coordinated as the postal Rural Free Delivery laws and the state-aid programs. There were also a handful of efforts to put together nation-spanning intercity routes, to allow urban residents and businesses to more easily travel to other big cities. These efforts often took the form of loose associations of individual entrepreneurs and local officials that spanned multiple counties, states, and regions. The best known of these was the Lincoln Highway, which was intended to stretch from New York City to San Francisco.

These efforts differed in both strategy and organization from Logan Page's arm of the road-building movement. Instead of a carefully engineered, tightly organized, and formal group working to enact systematic government road-aid, these individual regional and interregional highways were championed by separate ad hoc associations that would try to coordinate routing, signage, and maps, leaving the actual construction and financing to a patchwork of segment-specific initiatives. Some sections were built by local boosters and tourist-oriented businessmen along the route, others were completed as town or county roads, while others were not ever finished at all (until they were later taken over by the federal-aid highway system created by the 1916 act and its successors).

Since roads like the Lincoln Highway were not intended to be farm-to-market or postal delivery roads, they were denounced by some—especially farmers—as leisure accommodations for economic elites who did not need government help. They did, however, gather support from owners of hotels, gas stations, repair garages, and developers of real estate along the routes, as well as manufacturers and retailers of autos and auto parts. Even as this schism in the Good Roads movement was widening, the group that advocated systematic federal subsidies for farm-to-market highway construction achieved their landmark success: the passage of the Federal Aid Road Act of 1916.

The 1916 Act

The initial draft of the act was submitted to Congress by another of Page's carefully constructed professional associations, the American Association of State Highway Officials. The AAA promptly launched a campaign to support the bill, as did all of the other constituent groups in the highway lobby. Interestingly, the railroads supported the bill too, thinking that it would make it easier for people and goods to get to their stations. Many of these special interest groups tried to pressure Congress to make amendments that would aid their own specific interests. Amid this deluge of lobbying—almost all in support, but sometimes clamoring for conflicting adjustments—congressional leaders turned for advice to Page, as the leading expert in the field. So, in multiple ways, he was the guiding hand behind the act. Arguably, it was his crowning achievement.

One of the most important precedents established by the 1916 act was a direct outcome of Page's experiences traveling around to each of the state capitals and some of the difficulties that he ran into implementing the 1912 Rural Free Delivery program. He had seen up close that many of the states lacked the institutional and legal structures needed to administer federal road-building grants, so he arranged for the act to include a provision that directed every state to create a highway department. His agency laid out the exact required format for these departments and established a standardized procedure for planning, designing, and proposing highways.

The dollar-for-dollar matching grants that were the centerpiece of the legislation would flow only through these new state highway departments, not directly to any localities or to any other public entities, and not directly to any private road builders. Taken as a whole, these mandates prompted, by force of law, an orchestrated expansion of federal and state bureaucracies, supported by much of the of the nation's business community and almost 20 years before the New Deal. Furthermore, by statute and regulation, it placed highway engineers at the center of this new bureaucracy in Washington and in all of the state capitals. While many states already had highway departments, 27 had to make substantial changes to align with the law's new requirements. Eight other states created new departments entirely. Three of them had to pass constitutional amendments in order to comply.

One of the most important provisions of the 1916 act was contained in the technical details of the precedent-setting formula it used for dividing its \$75 million five-year authorization among the states. This same formula, which was based upon a combination of population, area, and existing road mileage, would be used in subsequent highway bills for many decades. By giving the same weight to a mile of single-lane dirt road as a mile along a main four-lane thoroughfare near a city (urban streets did not count at all in this formula) and simultaneously adjusting for each state's geographic size (in effect, twice—once with the area calculation and again with the adjustment for existing nonurban road mileage), the formula introduced yet another funding bias in favor of sparsely settled states at the expense of those states that were more urbanized.

Last, and not least, since the stated focus of the 1916 act was Rural Free Delivery routes, tolls were

forbidden on any roads that received the new federal aid. This, too, became an important precedent, one that would have long-lasting and pervasive impacts that persist to this day. By prohibiting tolls, the act kept the costs of driving well below the costs of providing the road to drive on, fostering the desire of drivers for more and more roads, since they did not need to pay the costs of the benefits that they received when they drove along the new modern highways. This underpricing of road use, along with many of the other core provisions of the Federal Aid Road Act of 1916, were repeated in every successive federal transportation legislation and played a part in rearranging American commuting patterns, housing choices, and lifestyles.

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See Also: Bureau of Public Roads; Economic Development; Federal Transportation Policy; Highway Finance; Road Pricing Schemes, U.S. and International; Rural Transportation Mobility; Transportation Impacts on Land Use; Transportation Planning and Politics; Urban Sprawl Versus Compact Development.

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Federal Automobile Safety Standards

By 1965, the automobile had become completely integrated into American life, and the number of vehicles on the road continued to increase significantly each year. Interstate travel also became

more common with the advent of interstate highways. As the number of travelers increased, so did concerns about road safety. That same year, Ralph Nader, a young lawyer and activist who had become impassioned about safety issues in automobiles, published *Unsafe at Any Speed: The Designed-In Dangers of the American Automobile*. The following year, the National Academy of Sciences released a trauma report, "Accidental Death and Disability—The Neglected Disease of Modern Society," in which it was estimated that 49,000 lives had been lost to automobile accidents the previous year. Together, these publications helped focus public attention on forcing automobile manufacturers to design vehicles that included enhanced safety measures. At that time, few vehicles included such features as seat belts, child restraints, or other crash protection measures. Pressure on legislatures led to widespread passage of laws designed to improve automobile safety. The U.S. Department of Transportation (DOT) was established in 1966. That same year, the National Traffic and Motor Vehicle Safety Act established the National Highway Traffic Safety Bureau, which subsequently became the National Highway Traffic Safety Administration (NHTSA). Thus, the groundwork was laid for the implementation of federal automobile safety standards.

Under Title 49 of the U.S. Code, NHTSA is responsible for both establishing and enforcing automobile safety standards and for monitoring manufacturers' recalls of faulty vehicles. Since January 1, 1968, the standards have mandated the manufacture of vehicles that are able to avoid crashes as much as possible and to protect drivers and passengers when crashes do occur.

Basic standards stipulate that vehicles must include such features as windshield defrosting and defogging systems, hydraulic and electric service braking systems, reflective lights, and warning devices such as blinkers and hazard lights. Standards for tire manufacturing and performance are also included. Protections for surviving crashes encompass such features as head restraints, air bags, side impact protection, roof crash resistance, and rear impact protection. These protections also mandate emergency exits on buses and helmets for drivers of motorcycles.

Establishing Safety Standards

Using authority granted in 1966 by the National Traffic and Motor Vehicle Safety Act and the

Highway Safety Act and in 1972 by the Vehicle Information and Cost Savings Act, the National Highway Traffic Safety Administration is responsible for implementing the Federal Motor Vehicle Safety Standards (FMVSS), which initially became effective on March 1, 1967. These standards impact all vehicles manufactured in the United States after January 1, 1968. In order to implement federal automobile safety standards, the NHTSA is charged with reducing deaths, injuries, and economic losses that result from automobile crashes. The NHTSA works closely with state and local governments to reduce accidents and to promote the use of safety measures that have been proven to reduce the number of automobile-related accidents.

The federal automobile safety standards are designed to force automobile manufacturers to build vehicles that are increasingly crash resistant. The standards deal with such measures as seat belts, child restraints, air bags, hydraulic and electric brakes, redesigning mid- and low instrument panels, tires, windshield defrosting and defogging systems, high-penetration resistant windshield materials, crush-resistant roofs, and overall impact protection. All of these measures are intended to make automobiles more resistant to damage when involved in accidents. Despite these measures, approximately 52,000 people die in automobile-related accidents each year. The federal government has consistently faced resistance from car manufacturers who resist the cost involved in increasing safety. That resistance has heightened during periods when the economy is sluggish and when competition from foreign car manufacturers is particularly high.

Impacts of Safety Measures

In 1960, few automobiles contained seat belts, and many people refused to use those that were installed. Even so, the National Highway Traffic Safety Administration estimates that 115 lives were saved by the use of seat belts during that year. In 2004, a report issued by the NHTSA examined the life-saving impact of safety technologies installed in American automobiles between 1975 and 1978, suggesting that approximately 328,551 lives had been saved by safety measures during that period. The overall conclusion was that automobile safety has been steadily rising as automobile manufacturers continue to comply with the federal automobile



The National Highway Traffic Safety Administration estimated that 32 percent of children aged 4 to 7 were not being restrained in car or booster seats in 2009, but by 2011, that number had fallen to 25 percent. In this age group, booster seats reduce injury risk by 59 percent compared to seat belts alone.

safety standards. Some manufacturers have also engaged in voluntary efforts to increase automobile safety, going beyond mandated standards. The number of lives saved by safety standards increased significantly after 1984 when mandatory seat belt laws were enacted in many states. As the number of automobile fatalities and nonfatal accidents decreased, so did the economic impact of those accidents.

In spite of improved automobile safety, approximately 52,000 lives are still being lost in automobile accidents each year. Experts believed that this high cost to human life is often the result of a failure to employ available safety technologies. No example of this is more evident than the use of seat belts. In 1968, federal automobile safety standards began mandating that automobile manufacturers install lap seat belts in all automobiles built in the United States. It took almost two decades, however, before

states began mandating the wearing of seat belts. In 2007, the NHTSA estimated that 63 percent of the 43,000 Americans killed in automobile-related fatalities were not wearing seat belts. The agency also found that adults 65 and over (75 percent) were more likely than other adults (62 percent) to be wearing seat belts when involved in an accident. Young drivers were least likely to wear seat belts, and the NHTSA reported in 2007 that 64 percent of young drivers killed while driving under the influence were not wearing seat belts.

The costs of failing to use available safety features is astronomical, and the NHTSA estimates that hospital costs for unbuckled victims of crashes is 50 percent higher than for those wearing seat belts. The brunt of these costs is borne by society, amounting to some \$26 billion annually and averaging \$580 per person per year. In addition to the high cost of medical care, there is a significant loss in national productivity related to failure to use automobile safety features.

Much attention has been paid to the use of child restraints in the early 21st century. In 2003, 34 percent of children aged 5 and under who were killed in automobile accidents had not been properly restrained. In 2009, the NHTSA estimated that 32 percent of children aged 4 to 7 were not being restrained in car or booster seats as required by most state laws. By 2011, however, the number of children in that age group who were being properly restrained had risen to 75 percent.

The computer revolution that began in the late 20th century has had a major impact on automobile safety, making it possible to gather data immediately before, during, and after automobile accidents in ways comparable to those used in determining the circumstances of airplane crashes. The ability to gather this information has major implications for setting future standards for automobile safety. In 2006, the National Highway Traffic Safety Administration established new standards for gathering information from these event data recorders (EDRs) installed in cars manufactured on and after September 1, 2012.

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See Also: Automated Vehicle Monitoring Systems; Automobile Safety Systems; Department of

Transportation Act of 1966; U.S. Department of Transportation.

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Federal Aviation Administration

Travel by air has always involved an element of risk; with that risk there has always been need for some form of government regulation and oversight. The

current role of the Federal Aviation Administration (FAA) is best understood in the context of its history, both chronological and historic. With the passage of the Federal Aviation Administration Reauthorization Act of 2009 and the 2011 enactment of NextGen, the FAA is poised to continue to evolve in the foreseeable future, creating an air transportation infrastructure that is the most economical, efficient, and reliable system in the world, with an eye on aircraft safety, air travel security, and environmental sustainability—in the words of its mission, "to provide the safest, most efficient, aerospace system in the world."

Though the history of powered, controlled flight of a heavier-than-air machine goes back to the Wright Brothers' exploit at Kitty Hawk, North Carolina, in 1903, few other people in the United States had actually seen a man fly until 1908, when the Wrights gave their first military demonstration and rival Glenn Curtiss first demonstrated the Aerodrome Number 3, better known as the June Bug, to the public.

In Paris, France, Alberto Santos-Dumont thrilled onlookers in 1906, when he first took to the air in his own powered aircraft, the 14-bis. One year later, throngs of people attended the Grande Semaine d'Aviation de la Champagne, held at Reims, France. By that time, the public was smitten by the miracle of flight. However, the aircraft was an invention in search of a role, be it entertainment or utilitarian. These early machines lacked the power, range, and reliability to carry an economically feasible payload.

It was World War I that saw the first use of the airplane as a potent weapon, first as a means to spy on the enemy and later as a machine to drop bombs and shoot down enemy airplanes and balloons. After the war, worn-out surplus airplanes were providing early air mail service. However, pilots had to rely on navigating by following roads and railways and a magnetic compass. Flying was a very dangerous enterprise; fatal crashes were routine. The first government intervention came with the Air Mail Act of 1925, also known as the Kelly Act. Though this legislation did not cover air safety, it did spur the creation of airline companies to which the government awarded contracts to carry the mail, shifting the costs of flying from the taxpayer to persons purchasing air mail stamps from the Post Office at fixed rates.

Origins

In the following year, the Air Commerce Act of 1926 established the Department of Commerce Aeronautics Branch to enact and enforce rules for the inspection of aircraft for airworthiness and the licensing of airmen that form the cornerstone of the FAA's activities today. Aircraft also were required to display conspicuous identification markings, the forerunner to the FAA N-number aircraft registration today. The agency also oversaw these regulations, along with rules governing navigational aids and aircraft altitude separation; these Civil Air Regulations were the forerunners of the current FAA Federal Air Regulations (FARs).

In 1934, the Department of Commerce renamed the agency the Bureau of Air Commerce; one of its first acts was to encourage the airlines to establish air traffic control (ATC) centers, monitoring air traffic en route between airport control towers. The bureau took control of these two years later, in 1936. The Civil Aeronautics Act of 1938 transferred the responsibilities of the Bureau of Commerce to a new, independent agency, the Civil Aeronautics Authority (CAA), to oversee aircraft and airman certification and to regulate air routes and fares. The authority included the Air Safety Board to conduct accident investigations and recommend ways of preventing future mishaps.

In 1940, President Franklin Roosevelt split the CAA into two agencies: the Civil Aeronautics Administration, which again became part of the Department of Commerce, and the Civil Aeronautics Board (CAB). The administration was still responsible for ATC, airman and aircraft airworthiness certification, enforcing safety regulations, and developing routes, while the CAB oversaw accident investigation and economic regulation of the airlines.

Federal Aviation Act of 1958

In the 1950s, despite the introduction of radar, air traffic control took on greater urgency. Most notable was the 1956 midair collision of a United Air Lines Douglas DC-7 and a Trans World Airlines Lockheed L-1049 Super Constellation, and there would be two more midair collisions before safety legislation could be in place. In addition, the significant difference in air speed between a veteran DC-3 and the new jets entering service became cause for concern. These events were behind the passage of the Federal Aviation Act of 1958, which transferred

the CAA's responsibilities to a new, independent agency, the Federal Aviation Agency (FAA), which oversaw all ATC and aircraft safety measures, as well as aircraft registration and awarding of air routes, in effect combining the roles of the CAA and CAB. When, in 1967, the FAA became part of the Department of Transportation, its name was changed to Federal Aviation Administration, as we know it today.

Evolution

Over the years, the role of the FAA would continue to change. In the wake of the airliner hijackings in the 1960s, it became involved in security measures. After the September 11, 2001, attacks, that task became the responsibility of the then newly formed Transportation Security Administration under the Department of Homeland Security.

Though air pollution and noise were serious problems with early turbojet-powered airliners, especially those that used water injection to provide extra engine thrust for takeoff, it was not until 1968 that the environmental aspects of aviation became part of the FAA's responsibility; this was primarily in response to the supersonic transports being developed in the United States, the United Kingdom, France, and the Soviet Union, and growing pressure from environmental groups. In 1970, the Airport and Airway Development Act gave the FAA responsibility for updating the nation's airports to accommodate the huge increases in civil airline traffic spurred by the jet age, ensuring that ATC centers and airport infrastructure would be safe for the air-traveling public. The Airline Deregulation Act of 1978 phased out the regulation of airline routes and airfares, previously the domain of the CAB. The same agency's accident investigation duties were assigned to the newly formed National Transportation Safety Board (NTSB).

The most spectacular experiment involved a Boeing 720, which the FAA purchased new in 1961 to train safety inspectors of pilots of jet airliners, which had recently entered service. This aircraft, originally N113, reregistered N833NA, was part of a joint exercise in 1984 with the National Aeronautics and Space Administration (NASA) to test the newly formulated antimisting kerosene (AMK), fuel specially treated so as not to ignite in the event of a crash. The airplane was remotely flown at Edwards Air Force Base in what was called the Controlled



This Federal Aviation Administration (FAA) Boeing 720 aircraft was destroyed in 1984 during a controlled crash intended to test a new antimisting kerosene fuel. The plane was remotely crashed at a runway at Edwards Air Force Base near Lancaster, California, in a joint experiment conducted by the FAA and the National Aeronautics and Space Administration.

Impact Project Demonstration (CID); the aircraft was to be flown into a series of metal cutting devices placed at the threshold of the main runway. The aircraft landed short of the runway, slammed into the cutting devices, skidded, and burst into flames. The results of the AMK were disappointing; however, cameras mounted inside the aircraft to film the effect of the impact on crash-test dummy “passengers” did yield some information on ways to make airliner cabins safer and less susceptible to the dangers of fire in the event of a crash. This is probably the only test in which an entirely airworthy airliner was deliberately flown and crashed.

The FAA bought a second jetliner in 1961, a Convair 880, registered N112. In 1981, the aircraft was transferred to the U.S. Navy (Bu161572). In 1995, however, its original owner, the FAA, used the retired aircraft for structural testing of explosive devices under the cabin floor. This was the first such test on an aircraft whose systems were completely operational. The ground test was performed to simulate an internal explosion at high altitude. (Similar tests were performed on scrapped airliners, most notably an ex-LTU Lockheed L1011 and a former Air France Boeing 747.)

As of 2013, the FAA had more than 44,000 employees participating in safety regulation, covering manufacturing and maintaining civil aircraft; airspace and air traffic management, operating a network of ATCs, control towers, and flight service stations and developing air rules, assigning airspace, and controlling air traffic; air navigation facilities onboard aircraft; promoting civil aviation safety abroad; regulating and encouraging the fledgling U.S. commercial space transportation industry; and assisting with civil airplane research, development, and engineering.

Specific programs include the Air Transport and Oversight System (ATOS) to ensure that airlines comply with regulations and safety standards; the Aviation Safety Action Program (ASAP) to promote aviation safety through accident and incident prevention by encouraging voluntary reporting of safety issues and events; the Aviation Health and Safety Program (ASHP); various awards programs for best practices in commercial and general aviation; the International Aviation Safety Assessments (IASA) Program; the National Airshow Program to ensure safety for pilots and spectators at civil and military air shows (including aerobatics);

the National Simulator Program (NSP); managing the storage and retrieval of records; Safer Skies, a major initiative of the General Aviation Joint Steering Committee (GA-JSC) to reduce fatal accidents among private (general aviation) aircraft; the Suspected Unapproved Parts (SUP) Program to ensure only certified replacement parts be used by air carriers and third-party maintenance facilities; the System Approach for Safety Oversight Program (SASO); and maintaining an effective Whistleblower Protection Program to ensure that anyone reporting unsafe or illegal conditions will be protected against any retribution.

With an eye on the future, the Century of Aviation Reauthorization Act of 2003 initiated the concept of NextGen, the Next Generation Transportation System, a multiagency effort to develop the safest, most efficient, and most secure aviation system possible by 2025. The first document, *Destination 2025*, outlines how the FAA is to accomplish five goals: move to the next level of safety, create the workplace of the future, deliver aviation access through innovation, sustain our future, and advance global collaboration. These documents and more will ensure the FAA fulfills its mission, through its vision, “to reach the next level of safety, environmental responsibility and global leadership” through its fivefold set of values: “Safety is our passion; Excellence is our promise; Integrity is our touchstone; People are our strength; Innovation is our signature.” These core values are also the basis of NextGen, enacted in 2011 as “a comprehensive overhaul of our National Airspace System to make air travel more convenient and dependable, while ensuring your flight is as safe, secure, and hassle-free as possible.”

The plan maps out what the agency needs to do to address economic, environmental, safety, security, and communication concerns. It is noteworthy that the FAA has restored one example of its most memorable aircraft (and the first aircraft to make commercial aviation profitable without government air mail subsidies), the Douglas DC-3 (TC-47K), N34, as a flying museum to teach the next generation about the values of the FAA and the history upon which this critical agency was built.

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See Also: Airline Deregulation Act of 1978; Airline Industry; Deregulation; Federal Aviation Administration Reauthorization Act of 2009; Federal Transportation Policy; Next-Generation Airports, Federal; U.S. Department of Transportation.

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Federal Aviation Administration Reauthorization Act of 2009

The Federal Aviation Administration (FAA) is an agency of the U.S. Department of Transportation.

It is responsible for regulating and supervising all aspects of civil aviation in the United States.

On February 9, 2009, the FAA Reauthorization Act was introduced in Congress as H.R. 915. It passed the House of Representatives by a vote of 277 to 136 on May 21, 2009. It included provisions for the Airport Improvement Program, studies of pilot fatigue and of runway lighting and safety, increases in fuel taxes for general-aviation planes, modernization of the air traffic control system, and major increases in passenger facilities fees. It also contained requirements for subsonic noise reductions and labor provisions, both of which were controversial. One provision covered the airport fire departments and their firefighters, who usually belong to a firefighters union. The president of the Memphis International Airport publicly stated that the bill's expansion of airport fire departments, increasing staff and equipment, was not acceptable.

The other significant labor provision (section 806), was widely viewed as favorable to labor organizing efforts or as a union payback to opponents. The FAA Reauthorization Act carried a provision that affected FedEx, one of the major courier delivery services in the United States. Based in Memphis, Tennessee, the FedEx Corporation was originally known as Federal Express and became FedEx in 2000. FedEx began with the delivery of packages using ground transportation, but its founder Fred Smith invented the concept of express delivery. For example, using the FedEx hub-and-spoke model of delivery, a package from Dallas bound for New York is delivered to the hub at Memphis by an airplane that returns on its Dallas-Memphis spoke, while the package is transferred at the hub to a plane from New York that returns on its spoke.

The system enabled FedEx to become a global leader in overnight deliveries of a variety of packages—especially those that may be low in value but are high in priority. It is a global transportation company that operates worldwide. It was also successful in preventing unionization of its business. One way to accomplish this was to identify and hire drivers as independent contractors. It does not engage in direct supervision of its drivers' work performance. It does provide suggestions and best practices for performances of assigned tasks, but it does not have the authority to require compliance with its suggestions under its independent driver agreements.

The use of independent contractors as drivers by FedEx was challenged by the Internal Revenue Service (IRS), which in 2008 reversed its classification of FedEx drivers as independent contractors, saying the classification had been in error. They were actually employees, the IRS claimed, and therefore FedEx owed more than \$300 million in back taxes. The IRS later revised its decision and returned to its original classification of FedEx employees as independent contractors. However, other political forces were at work, and among them were unions, rival United Parcel Service (UPS), and states eager to collect taxes from FedEx.

FedEx described the bill as a legislative bailout for those who wanted to gain money from FedEx and those who wanted to harm its competitive position. The provision affecting FedEx authorized its drivers to organize collective bargaining units under the terms of the National Labor Relations Act (NLRA) and eliminated the requirement that any organizing efforts be conducted according to the rules of the Railway Labor Act (RLA).

The dispute in part involved UPS, with support from the International Brotherhood of Teamsters and the nonairline personnel working at FedEx. The UPS ground workers were organized under the NLRA provisions, which allowed organization of union units at work sites on a site-by-site basis. The airline workers of UPS were covered by RLA rules. In contrast, all FedEx drivers had been covered by the rules of the RLA, which required unionization nationally. Because the RLA rules made it harder to unionize, there was a lower rate of unionized workers.

In public statements, FedEx said that if the bill were to pass the Senate and become law, those who rely on next-day delivery service for medicine, critical parts, or essential goods would pay the price of this political manipulation that would reduce competition; it would eventually expose the public to the effects of strikes involving union workers at FedEx, and the effects would disrupt essential overnight or time-sensitive deliveries of high-value shipments. The Teamsters responded with an Internet campaign that argued that FedEx drivers were not airline pilots, therefore FedEx's ground drivers should be covered by the NLRB and not by the RLB.

The impact for rival UPS would have been insignificant because its drivers had been organized and operated as members of the Teamsters Union.

Those opponents of FedEx assumed that unionization would increase costs for FedEx and thereafter reduce its competitive advantage to the benefit of UPS and others. Consequently, some pundits began to call the bill a brown bailout, referring to the brown uniforms of UPS drivers.

UPS had engaged in lobbying efforts for the adoption of the FAA Reauthorization Act of 2009 (H.R. 915). FedEx's lobbyists used the term *bailout* to characterize the law as giving an economic subsidy to a competitor that was inefficient. Critics of the FedEx lobbying effort claimed that the use of the term *bailout* was unethical.

Regardless of criticism from independent political observers, the term *bailout* was a buzzword used frequently in 2008 to describe the Emergency Economic Stabilization Act of 2008. Bailouts providing subsidies for failing companies and government institutions were authorized. It may have been unethical to apply the term to benefits for UPS, which was not in financial trouble, but it was very effective politically in framing the public debate for FedEx. Other interest groups also supported FedEx's position and lobbied Congress to defeat the bill.

On June 1, 2009, the Senate received and introduced the House version of H.R. 915. It was read twice and then referred to the Senate Committee on Commerce, Science and Transportation. The bill was passed on March 22, 2010, in a Senate version. This version did not include the provision that FedEx opposed. Without the controversial labor provision, the bill was sent to an ad hoc conference committee that was to reconcile the differences between the two versions of the bill, as constitutionally required in the bicameral system of Congress. The deadline for reconciliation was June 30, 2010; however, the deadline passed without reconciliation being accomplished, which killed the bill, preventing its enactment as law.

In the legislative work on the FAA Reauthorization Act, Senator Claire McCaskill (D-MO) inserted language in the bill to address the problems associated with outsourcing airline maintenance to foreign repair stations. The legislation addressed the fact that work performed at foreign repair stations created economic issues as well as safety issues. Also it would also close loop holes that were allowing threats to national security.

The bill was amended to provide protection for whistleblowers from retaliatory actions when they

reported unsafe airline practices. The protections would be supported by actions of the FAA's Office of Whistleblowers.

In 2012, the 112th Congress amended the Federal Aviation Administration Reauthorization Act of 2009 in an appropriations bill. It was published on February 14, 2012, as Public Law 112-95 (126 STAT 11). It provided funding, support for next-generation aircraft emerging from research and experimental testing and the airport systems needed to handle them, ways to collect passenger facility charges, airport improvement programs, and more.

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See Also: Air Cargo Carriers; Air Passenger Carriers; Federal Aviation Administration; U.S. Department of Transportation.

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Federal Highway Act of 1921

The Federal Highway Act of 1921 was more than just the routine reauthorization of the groundbreaking Federal Aid Road Act of 1916. It contained significant adjustments and enhancements to the earlier legislation, stabilizing the experimental federal-aid highway grant program, which had faced

logistical and political difficulties. By building on the precedents established in 1916 and by introducing important new precedents, the 1921 act initiated a golden age of highway building in the United States that lasted for half a century.

The most important provision of the act was the requirement that each state formally designate 7 percent of its total road mileage as “federal-aid highways,” further divided into primary routes and secondary routes. This marked the first official creation of a nationwide system of hierarchically designated highways. The act formally defined primary routes as interstate roads and mandated that each state spend at least 60 percent of its federal-aid allocation on these projects. Furthermore, each state was required to develop official maps that designated 3 percent of their total road mileage as these primary routes. The other federal-aid highways in each state, making up 4 percent of the total, were defined as secondary routes that served intercounty traffic in rural areas and were allocated the remaining 40 percent of the federal grants. Urban roads were still excluded from federal support, in keeping with the provisions of the 1916 act, which had been exclusively focused on farm-to-market and rural post roads.

National Highways

This new provision not only got the nation started toward a coherent system of nationwide roads, it also served two important political purposes. First, it re-established consensus by reuniting the battling factions of the highway lobby. Since the 1916 act had passed, with its exclusive focus on rural routes, the proponents of long-distance interstate roads had become increasingly critical of the federal-aid program, pushing for alternative approaches to road building. A proposal for a national highway commission—rather than the decentralized model that had been created in 1916, made up of state highway departments supported by federal grants—had been gaining support.

Meanwhile, other groups continued to move forward with ad hoc interregional highway initiatives like the Lincoln Highway Association, which been formed to stitch together a road from New York to northern California, via Pittsburgh, Indianapolis, Chicago, Omaha, and Salt Lake City. Another group was trying to assemble a route called the Dixie Highway, from Chicago to Miami. A third group

pushed for the Robert E. Lee Highway, from New York to New Orleans. A fourth group tried to enlist political support for the John Bankhead National Highway, which would go from Washington, D.C., to San Diego by an indirect route passing through Atlanta, Charlotte, Memphis, Birmingham, and Little Rock—not to be confused with the proposed National Highway from New York to Atlanta, or the competing group pushing for the so-called Capital Highway from Washington to Atlanta. The 1921 act ended this debate, responding to the clamor for long-distance highways by formally establishing a national highway system of primary routes that would be coordinated and funded by a federal agency in partnership with the state highway departments.

Second, by expanding the scope of the existing grant program, and by mandating additional technical tasks, the 1921 act strengthened and further entrenched the existing institutional structures. The state highway departments and the federal Bureau of Public Roads (BPR) became larger and stronger as they geared up for mapping the new national network of primary and secondary routes. Furthermore, the 1921 act directed the BPR to promulgate minimum paving standards, minimum roadway widths, maximum grades and curvatures, and other technical rules. Overall, while the 1916 act had produced a highly structured highway funding mechanism and forced the creation of a new bureaucracy, it was the 1921 act that confirmed and buttressed these institutional arrangements.

Antiurban Approach

The 1921 act repeated the antiurban slant that had been embedded in earlier highway legislation. Not only did it continue to forbid any grants to roads in urban areas, it also renewed the cap on aid-per-mile, effectively providing lower support levels for routes that needed to be wider or passed through areas with higher land costs. The cap was raised, from \$16,000 per mile in the 1916 Act, to \$20,000 in the 1921 Act, but construction costs had gone up by almost 90 percent during the same period, so this was not a substantial increase.

Furthermore, the antiurban slant of the nascent federal highway program was increased by the 1921 act. On its face, the act seemed to continue the 1916 act’s practice of providing matching grants to the states on a 1:1 basis. In other words, the federal

government would provide 50 percent of the funds for approved road projects. But, one of the technical provisions of the 1921 act adjusted this matching ratio by taking into account the federally owned land in each state. Ostensibly, this provision was justified on the grounds that the federal land was not subject to local taxes. But, in effect, it provided much more attractive terms for western and rural states, compared to eastern urbanized states. For example, instead of the 1:1, or 50–50, matching arrangement enjoyed by northeastern states, Nevada enjoyed an 8:1 matching ratio, meaning that the federal government paid for about 88 percent of the costs. Utah benefited from a matching ratio of 3:1 (a 75–25 split). Wyoming's ratio was 2:1, for a 67–33 split. Arizona, Colorado, Idaho, and New Mexico also benefited from substantially better terms.

Thomas MacDonald

Much of the behind-the-scenes work on the 1921 act was carried out by Thomas MacDonald. MacDonald had taken over as the top federal highway official in 1918 after the death of Logan Page. At that time, the federal-aid highway grant that had been created by the 1916 act and had been administered by Page's Office of Public Roads was struggling with rapidly escalating costs, fragmenting political support, and partnership with underdeveloped state highway departments. Under MacDonald's leadership the agency, now renamed the Bureau of Public Roads, rebuilt political consensus, acquired increased funding, and worked assiduously to augment the state highway departments. MacDonald had formerly been in charge of the Iowa department, so he knew what types of technical support the states needed from Washington. In 1919 and 1920, the program began to achieve some results, so that by the time the 1921 act was proposed, MacDonald could point to a successful track record.

Funding

The entire program was funded without any federally imposed charges on motorists. Tolls were explicitly banned from all roads funded with the federal-aid grants, and there was not yet a federal gas tax. MacDonald was known to say that tolls were an infringement on individual freedom. However, since at this time a very small portion of Americans owned automobiles or even knew how

to drive, and more than half of the country lived in urbanized areas that would not benefit from the new federal grants, the entire program amounted to a transfer of funds from urban to rural and from nondrivers to drivers.

While the 1916 act had initially provided for \$75 million in grants over five years, it quickly became clear that this sum was insufficient. In 1919, MacDonald was able to secure an additional \$50 million, followed by \$75 million each in 1920 and 1921. The 1921 act provided for \$75 million per year for five years. Not only was this five times the amount funded in 1916 but it also allowed for multiyear project commitments, and MacDonald would not need to return to Congress each year to ask for an annual budget allotment.

The new flow of funds, as well as MacDonald's careful organizational and political work, soon achieved results. By the end of 1920, the 1916 program had produced almost 3,000 projects, covering almost 30,000 miles. While all of these were disconnected farm-to-market roads that did not yet form a coherent national network, the program nevertheless demonstrated that the new federalist system, with central funding and coordination, in partnership with state-based construction and implementation, could produce consistent results.

The 1921 act, with its new emphasis on building a rudimentary system of nationwide long-distance routes while continuing the work on farm-to-market roads, was the second-generation version of the 1916 program. Within a decade of its passage, the 1921 act had put a designated federal-aid road within 10 miles of 90 percent of the U.S. population.

State and Local Burden

As the program expanded in size and scope, it became more expensive for state and local governments to keep up with their funding obligations. They started to take on debt in order to raise their money to pay their share. Furthermore, the 1921 act included an obligation that the states provide adequate resources to maintain the federal-aid highways. The federal grants could be used only for new construction, not for maintenance or repair. This led to a substantial financial burden, and the states often turned to gas taxes, license fees, and vehicle registration fees.

Still, even with the emergence of these new user fees, it was estimated that motorists were still paying

less than a third of the \$1.5 billion that was being spent on roads and streets nationwide by the mid-1920s. Within city limits, the burden fell almost entirely on local property taxes, because of the exclusion from the federal program and because the states could barely keep up with matching their federal grants and paying for maintenance of their designated federal-aid primary and secondary routes.

The national highway map that was developed under the 1921 act introduced the practice of standardized route numbers that are still used today, with even-numbered routes going east-west and odd-numbered routes going north-south. This convention would later be duplicated for the Interstate Highway System.

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See Also: Bureau of Public Roads; Economic Development; Federal Aid Road Act of 1916; Federal Transportation Policy; Highway Finance; Road Pricing Schemes, U.S. and International; Rural Transportation Mobility; Transportation Impacts on Land Use; Transportation Planning and Politics; Urban Sprawl Versus Compact Development.

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Federal Highway Administration

Headquartered in Washington, D.C., and operating under the auspices of the U.S. Department of Transportation, the Federal Highway Administration (FHWA) is responsible for exercising oversight of the construction, maintenance, and preservation

of all highways, bridges, and tunnels in the United States. The FHWA provides technical support in these areas, working closely with state departments of transportation and with those involved in operating and maintaining federally owned lands. The FHWA's annual operating budget of \$30 billion is generated by excise taxes on fuel and motor vehicles. Through the Federal Aid Highway Program and the Federal Lands Highway Program, the FHWA also provides financial assistance to state and local governments and federal lands. The latter area encompasses national parks, national forests, Native American tribal lands, and all other federal lands. The FHWA is also involved in partnerships with federal and state agencies, nonprofit organizations, and the private sector, working together to carry out assigned tasks and promote the needs of the highway sector and the American people.

The Federal Highway Administration is involved in a range of core fields, and all have a major impact on the transportation sector. In the area of highways, it is responsible for overseeing highway funding, road operations and congestion, roads and bridges, road users, and highway safety. The FHWA's authority also extends to exercising oversight of highways at border crossings. Protecting the environment continues to be of major importance, and the FHWA has responsibilities in the areas of supporting wetland banking, restoring habitats, engaging in historic preservation, improving air quality, cutting down on noise pollution, mitigating the negative impacts of climate change, providing facilities for pedestrians and bicyclists, and protecting wildlife by providing designated wildlife crossings.

History

In 1893, as the sight of automobiles was becoming more common in the United States, the Office of Road Inquiry was established. In 1905, as the number of cars on American roads continued to increase, the name of the agency was changed to the Office of Public Roads, which operated under the auspices of the U.S. Department of Agriculture. A decade later, the name of the organization was changed to the Bureau of Public Roads. The name of the agency was again changed in 1939 when it began operating as the Public Roads Administration under the Federal Works Agency. That agency was abolished in 1949, and the transfer to the Department of Commerce signaled a name change

back to the Bureau of Public Roads. On October 15, 1966, the Federal Highway Administration was established. The following year, the FHWA took on all responsibilities previously assigned to the Bureau of Public Roads.

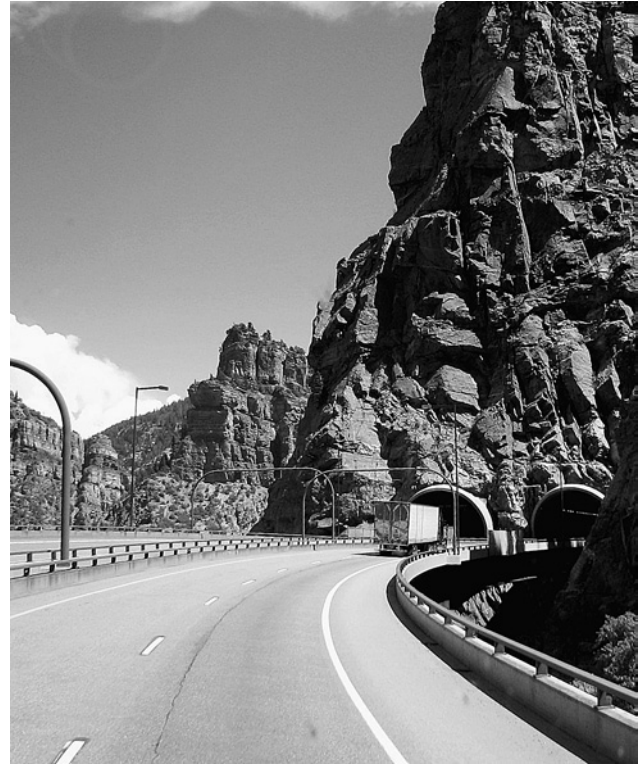
Within the context of passing the Federal Highway Act of 1938, Congress made its first official recommendation to build an interstate system designed to cross the United States in all directions, bringing all the states together and connecting them with Canada to the north and Mexico to the south. The act instructed the Bureau of Public Roads to investigate the possibility of building three superhighways that stretched across the country from east to west and three that would traverse the nation from north to south. Oversight of those first interstate highways—as well as the many others built over time—came to be one of the major responsibilities of the Federal Highway Administration.

Research and Technology

Major research projects overseen by the Federal Highway Administration include the Turner-Fairbank Highway Research Center (TFHRC) and FHWA Priority Market-Ready Technologies and Innovations. Turner-Fairbanks Highway Research Center, located in McLean, Virginia, houses the FHWA's Office of Research, Development, and Technology. The facility conducts both applied and exploratory research in areas such as vehicle-highway interaction, human-centered systems, and intelligent transportation systems.

FHWA Priority Market-Ready Technologies and Innovations coordinates research and technology not only for the FHWA but also for state research and technology programs, the National Cooperative Highway Research Program, University Transportation Center programs, the Intelligent Transportation Systems program, and various private-sector and nonprofit research and technology programs. The facility also cooperates with international agencies such as the Organisation for Economic Co-operation and Development (OECD) and the Federation of European Highway Research Laboratories.

Cooperative research is integral to the FHWA's mission to make American roads among the safest and most technologically advanced in the world. In 1997, for instance, the Federal Highway Administration joined the Standing Committee



A truck enters the Hanging Lake Tunnel on Interstate 70 in Colorado in 2008. The Glenwood Canyon project that included the tunnel was one of the last pieces of the U.S. Interstate Highway System to be finished, with construction beginning in 1980 and ending in 1992, at a cost of \$490 million.

on Highway Traffic Safety of the American Association of State Highway Transportation Officials (AASHTO), the National Highway Traffic Safety Administration (NHTSA), and the Transportation Research Board (formerly the Highway Research Board) to develop the AASHTO Highway Safety Plan to address a broad spectrum of issues related to improving travel on U.S. highways. One core research area that arose from the joint project was the commitment to address the needs of older drivers as baby boomers continue to age over the coming decades.

Innovation

The Federal Highway Administration has long been recognized for its willingness to try new technologies and for successfully implementing those that prove beneficial. In 1988, the FHWA created the Strategic Highway Research Program. Two of the most successful innovations to come out of that

initiative were the widespread use of Superior Performance Asphalt PAVements (Superpaves) and improved methods for maintaining highways during winter months in areas that experience harsh weather conditions. In 2004, the FHWA established the Highways for LIFE fund, which is implemented through congressional funding, to assist state departments of transportation in implementing innovative ideas.

In order to carry on the work begun by the first Strategic Highway Research Program, the FHWA launched the Second Strategic Highway Research Program (SHRP 2) in 2005 with funding from Congress. The goal of the second initiative is to turn innovative ideas into successful practices. The head of the FHWA is heavily involved in the program, and the deputy administrator provides daily leadership. Each state has created a Transportation Innovation Council, and these groups make decisions about the particular innovations that meet the needs of individual states.

Technologies instituted through SHRP2 include the use of warm-mix asphalt, the employment of geosynthetic reinforced soil-integrated bridge systems, and the inclusion of prefabricated bridge elements for use in bridge construction and repair. Additionally, 40 states have begun using the Safety Edge, which shapes the pavement edge at a prescribed angle during construction, resulting in increased safety for motorists.

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See Also: American Association of State Highway Transportation Officials; Bureau of Public Roads; National Highway Traffic Safety Administration; Transportation Research Board; U.S. Department of Transportation.

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Federal Motor Carrier Safety Administration

The Federal Motor Carrier Safety Administration (FMCSA) is a federal regulatory agency that was established January 1, 2000. Headquartered in Washington, D.C., it regulates the trucking industry in the United States and employs over 1,000 people in all 50 states and in the nation's capital. Its regulatory work is focused on improving the safety of commercial motor vehicles (CVM) and truck drivers through the promulgation and enforcement of safety regulations.

The FMCSA was authorized by the Motor Carrier Safety Improvement Act of 1999. It is a separate administration within the U.S. Department of Transportation. Previously, it had been a unit of the Federal Highway Administration. It is organized into three units called "ART," from the name of the subunits of the Offices of Analysis, Research, and Technology. Its primary mission is to reduce the number of accidents, injuries, and fatalities involving large trucks and buses on America's highways.

There are 14 key programs operated by the FMCSA: Border and International Safety, Commercial Driver's License Program, Enterprise Architecture, Federal Motor Carrier Safety Regulations (FMCSRs), Hazardous Materials Regulations (HMRs), Household Goods Program, Medical Program, Motor Carrier Safety Assistance Program (MCSAP), Motor Carrier Safety Identification and Information Systems, New Entrant Safety Assurance Process, Passenger Carrier Program,

Performance and Registration Information Systems Management (PRISM), Research and Analysis (R&A), and the Safety Education and Outreach program. These programs are part of the FMCSA's strategy to save lives.

Safety Programs

The Border and International Safety program is part of FMCSA's work in developing uniform standards or at least compatible motor carrier safety requirements and procedures throughout North America. It works with the governments of Canada and Mexico to ensure that Mexican and Canadian drivers of commercial motor vehicles in the United States meet the same safety standards as do American drivers.

The Commercial Driver's License Program develops, monitors, and supervises compliance with federal commercial driver licensing standards. These are the standards that commercial motor vehicle (CMV) drivers must meet to get a commercial drivers' license (CDL). The standards set by the FMCSA are the minimum standards that are uniformly applied across all of the jurisdictions of the United States. States are free to set higher standards and to manage the examination and granting of CDLs to applicants.

The FMCSA's Enterprise Architecture is a program that seeks to develop information technology systems. The "plan" or "blueprint" that the FMCSA is developing is its emerging guide to how develop and manage information technology. The plan is called Enterprise Architecture by FMCSA.

The Federal Motor Carrier Safety Regulations (FMCSRs) program is being developed and maintained in order to enforce federal regulations. The regulations are promulgated and enforced in order to promote carrier safety, industry productivity, and new technologies. The safety regulations are a baseline for safety requirements for operating commercial vehicles. The regulations also establish rules for drivers, carriers, vehicles, and vehicle equipment.

The Hazardous Materials Regulations (HMRs) program is designed to safeguard the public from dangers posed by the transportation of hazardous materials. The HMR rules address the classification of hazardous materials, proper packaging, employee training, hazard communication, and operational requirements.

Moving van companies are regulated under the FMCSA's consumer protection program, which it calls the Household Goods Program. Companies

that move household goods are required to register with the FMCSA, which uses a Web site (www.ProtectYourMove.gov) to assist consumers moving across state lines. It also has a toll-free hotline (1-888-368-7238) and a Web site (nccdb.fmcsa.dot.gov) for consumer complaints on interstate movers.

The FMCSA Medical Program promotes safety on the nation's highways by setting policies and standards for the health of CMV drivers. FMCSA publications and medical regulations seek to ensure that drivers operating in interstate commerce are healthy and physically fit to drive safely.

The Motor Carrier Safety Assistance Program (MCSAP) is a federal grant-in-aid program that provides states with financial assistance to hire staff and implement strategies to enforce the Federal Motor Carrier Safety Regulations and its Hazardous Materials Regulations programs. MCSAP funds are used to conduct roadside inspections and review motor carriers' compliance with FMCSRs and HMRs. MCSAP funds promote detection and correction of commercial motor vehicle safety defects, commercial vehicle driver deficiencies, and unsafe motor carrier practices before they become contributing factors to crashes and hazardous materials incidents.

The Motor Carrier Safety Identification and Information Systems program provides safety data. The data include state and national crash statistics and current analysis results, as well as detailed motor carrier safety performance data. The information is provided to both the industry and the public. The data is used in enforcement because it allows federal and state enforcement officials to target inspections. It also directs inspectors to areas where investigations can focus on higher risk carriers, vehicles, and drivers.

The New Entrant Safety Assurance Process allows new companies to enter the CMV market, but only after careful inspection. New companies must apply for a license and receive a USDOT number. The program also ensures that drivers and new companies entering the CMV market are knowledgeable about federal motor carrier safety and hazardous materials regulations. New entrants are monitored for an 18-month probation period. During that time the new carrier has to pass a safety audit. It also has to maintain safe operations to receive permanent USDOT registration. If a new motor carrier fails to maintain adequate basic safety

management controls, it may have its temporary USDOT registration revoked.

The Passenger Carrier Program supervises implementation of key actions within the U.S. Department of Transportation's Motorcoach Safety Action Plan. The Passenger Carrier Program is administered by FMCSA's Commercial Passenger Carrier Safety (PCS) Division, which is housed within the agency's headquarters. The mission of the PCS Division is to reduce crashes, injuries, and fatalities involving passenger-carrying commercial motor vehicles while ensuring the safe and accessible transportation of bus passengers. The PCS Division is responsible for administering the Americans with Disabilities Act Compliance Program for over-the-road bus companies. It also develops the agency's policies and programs for passenger carrier-related matters. And it participates in all passenger carrier-related activities, including rulemaking, research, data management, and outreach projects.

PRISM

The Performance and Registration Information Systems Management (PRISM) is a joint effort of the federal and state governments to ensure that commercial motor vehicle drivers drive safely. Safe performance is therefore a requirement for obtaining and keeping a commercial vehicle registration for a company, as it is for a CDL driver. The PRISM program links federal motor carrier safety records to every state's vehicle registration program. CMV companies have an assigned USDOT number that must be displayed on its vehicles. Each vehicle can be identified and its safety record assessed to determine the carrier is meeting safety standards. The determination of the carrier's record is made before the carrier can be issued license plates for its vehicles. The program allows safety performance to be monitored continuously. If a carrier fails to meet safety standards, its license to operate CMVs in interstate commerce may be revoked and the company will then no longer be able to register its vehicles. The use of the PRISM program is playing a major role in removing unsafe drivers and high-risk companies from the nation's highways.

A growing number of accidents involving commercial vehicles led to the development of PRISM. Interstate carriers were increasing rapidly in number, and with the increase in carriers came a corresponding increase in CMV accidents. PRISM

has been able to increase federal and state safety efforts with efficiency and effectiveness by quickly and accurately identifying highest risk carriers who have the most accidents. These are the highest risk carriers. Compliance review, roadside inspections, and other issues are efficiently examined. Scarce resources are used more carefully in compliance reviews and roadside inspections.

Motor carriers are required through the PRISM program to improve their identified safety deficiencies. If they do not comply, they will experience a series of increasingly stringent sanctions. The ultimate sanction is a Federal Out-of-Service order. The Federal Out-of-Service order is accompanied by concurrent state registration suspensions. To date, the PRISM program has been an effective way to motivate motor carriers to attend to safety issues and to make all changes necessary to eliminate safety deficiencies and compliance failures.

Congress mandated the PRISM program as a pilot project in the Intermodal Surface Transportation Efficiency Act of 1991. The pilot program was developed by the FMCSA and the state of Iowa. Four other states (Colorado, Indiana, Minnesota, and Oregon) participated along with Iowa in the pilot project. The pilot project ended in 1997 after it demonstrated that sanctions applied through state commercial vehicle registrations were effective tools for increasing motor carrier safety. With positive results in hand, Congress authorized funding for a national expansion of the PRISM program in the Transportation Equity Act for the 21st Century (TEA-21). Beginning with fiscal year 2006, more funding has been authorized for the PRISM program in the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy of Users (SAFETEA-LU). The Moving Ahead for Progress in the 21st Century Act (MAP-21) (Public Law 112-141, Sections 32602 and 32603) has authorized PRISM program funding for fiscal year 2013 to 2014.

Other Research and Outreach

The Research and Analysis (R&A) program seeks to study basic questions in order to develop applicable knowledge for road safety. The goal is to develop new methods and technologies that will make trucks and buses safer and more secure. Actions to achieve its research goal include conducting rigorous studies aiding the development of a science of vehicle safety. The basic research gains are used to

develop innovative best practices for drivers, vehicles, and carrier operations.

Technologies are being developed that can be deployed. Researchers examine traffic wrecks, injuries, and fatality events in order to develop a program that contributes to making vehicle operations—especially commercial vehicle driving—safe and secure. The research projects seek to identify techniques that will ensure that commercial drivers meet the physical and mental demands of their work. Other research is aimed at discovering ways to improve vehicle performance in a safe manner through vehicle-based safety technologies. Research supports efforts to apply safety management principles to enhance safe driving. Studies of the best management and communication practices are conducted to aid in enforcement of carrier-related regulations. Some research seeks to advance safety through information-based initiatives and information systems and technologies. Studies to improve security benefits to commercial carriers are also conducted. Finally, the most fundamental element is addressed by studies that focus on motivation toward excellence. The professional goal that the FMCSA has set for itself is to improve its service to its customers and stakeholders.

The Safety Education and Outreach program is focused on education. The program uses various educational strategies to increase compliance with safety regulations. The goal is to reduce commercial vehicle accidents. Its educational messages are aimed not only at commercial vehicles but at all roadway users, including pedestrians, bicyclists, and the driving public.

The Compliance Safety Accountability (CSA) program was begun in 2008 in field tests in Colorado, Georgia, Missouri, and New Jersey. In 2009 Delaware, Kansas, Maryland, Minnesota, and Montana were added to the field tests. The CSA program replaced the “SafeStat” model that had been used to measure safety performances. In the summer of 2010 data was available so that both carriers and drivers could see their records in the Behavior Analysis and Safety Improvement Category (BASIC). BASIC is the database where safety information is stored. The results could be contested after posted in BASIC.

The CSA program was challenged in federal court by the National Association of Small Trucking Companies, the Expedite Alliance of North

America, and the Air and Expedited Motor Carriers Association, organizations claiming to represent about 2,750 small carriers, who alleged that FMCSA has not followed proper procedures before publishing the data. Their petition for an injunction was, however, denied by the U. S. Court of Appeals for the District of Columbia.

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See Also: Driver Licensing, Commercial; Hazardous Materials Transport; Intermodal Surface Transportation Efficiency Act; Moving Ahead for Progress in the 21st Century Act; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Transportation Equity Act for the Twenty-First Century; Truck Inspections and Vehicle Licensing; U.S. Department of Transportation.

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Federal Railroad Administration

The railroad industry in the United States plays a critical part in the nation's economy and represents perhaps its most effective means of transportation. Passenger volume carried by the U.S. rail system can be measured in the hundreds of millions (650 million in 2011). Passenger service represents a substantial investment and service but happens to be the weakest part of rail service in the country. The most important aspect of the rail system, and the one in which the United States is a world leader, is the transportation of freight. American freight transport exceeds both the scale and effectiveness of anywhere else, especially compared to Europe, where trucks are used to ship a large portion of freight. American rail companies have also transported freight over the decades at decreasing costs to their customers.

In addition to the service it provides to the national economy by moving passengers, commodities, and goods, the American rail industry also contributes to the economy through its investments in infrastructure and the salaries it pays its workers. As a major component of the nation's transportation infrastructure and economy, it is regulated and monitored by the U.S. government, specifically, the Federal Railroad Administration.

Role and Organization

As one of several agencies that compose the U.S. Department of Transportation (USDOT), the Federal Railroad Administration (FRA) is the governmental regulatory agency that oversees all railway operations in the United States. The FRA's stated mission is to "enable the safe, reliable, and efficient movement of people and goods for a strong America, now and in the future." Currently, the FRA regulates more than 760 railroads throughout the country.

The FRA has several areas of responsibility of which its focus on safety is the most important. It

issues and enforces all federal safety regulations pertaining to railroads. It also exists as a research organization concentrating on safety, policy, technology, and other issues. It administers railroad assistance programs. Further, the FRA has special responsibility for the maintenance and improvement of rail service in the Northeast Corridor (essentially the Boston-to-Washington rail route).

The FRA came into being in 1966 as a result of the Department of Transportation Act of 1966, which created the USDOT and its subsidiary organizations. It assumed the safety and regulatory activities for rail transport that had previously been part of the oversight of the Interstate Commerce Commission. As of 2012, the FRA's staff numbered approximately 900, with an annual budget in excess of \$1.6 billion. Its chief, the administrator, reports directly to the secretary of transportation and is the principal adviser on all railroad matters to the secretary. The administrator is the principal representative of the U.S. Department of Transportation on railroad affairs.

The FRA is organized into offices that support internal operations as well as the core responsibilities of the agency. The first of these offices is the Administrator's Office. According to its mission statement, the Administrator's Office has overall responsibility for federal railroad policy (passenger and freight), legislative matters, safety issues and regulations, and the creation of a positive working environment within the administration.

Other support organizations in the FRA include the Offices of Communications, Civil Rights, Public Engagement, and Administration. The chief financial officer is responsible for the Office of Financial Services and the Office of Budget. The chief counsel oversees the Safety Law and General Law divisions. The remaining two offices are directly concerned with railway issues. These are the Office of Railroad Safety and the Office of Railroad Policy and Development.

The Office of Railroad Safety is divided into three main sections. These are the Office of Safety Analysis, the Office of Safety Assurance and Compliance, and the Offices of the Regional Administrator. There are eight of these FRA Regional Offices. The Office of Safety Analysis comprises 14 areas of responsibility, each assigned to a division. Seven of these (safety regulating analysis, highway rail crossing and trespassing, risk reduction, railroad safety technical

training standards, state rail safety participation, railroad safety information management, and safety program management) are managed by the Office of Safety Analysis. The second area under the Office of Railroad Safety is the Office of Safety Assurance and Compliance, which comprises divisions that have responsibility for operating practices; hazardous materials; industrial hygiene; motive power and equipment; track, signal, and train control; and rail and infrastructure.

The third area under the Office of Railroad Safety consists of the eight regional safety field offices. These offices conduct a wide range of safety-related operations. The staff in these regional offices conduct safety inspections of railroads (areas inspected are those within the general areas covered by the office's safety divisions and include motive power, tracks, signals, hazardous materials, and structures). Regional safety staff members assist the National Transportation Safety Board (NTSB) in the investigation of accidents, act as expert witnesses, and investigate the failure of safety devices. The staff also support the efforts to create and enforce "Quiet Zones" (crossings where trains cannot sound their horns in order not to increase noise in residential areas). The field offices are located in Cambridge, Massachusetts (Region 1), Crum Lynne, Pennsylvania (Region 2), Atlanta, Georgia (Region 3), Chicago, Illinois (Region 4), Ft. Worth, Texas (Region 5), Kansas City, Missouri (Region 6), Sacramento, California (Region 7), and Vancouver, Washington (Region 8).

The regional office operations are managed by the chief safety officer, who oversees the regional administrators, and include safety inspector training (for both state and federal inspectors) to train the staff who make inspections. It also enforces regulations, collects information, and generates reports (readily available on the FRA Web page) dealing directly with railroad accidents or safety issues. It also monitors and reports on train accidents and safety-related incidents.

It is worth noting that while the Office of Railroad Safety is responsible for setting and enforcing rail safety policy, it does not conduct the investigations following a rail disaster. That function is performed by the NTSB, an independent agency not part of the Department of Transportation. In the event of a railway accident (collision, derailment, or the release of toxic substances), inspectors and other staff from

the Railroad Safety office participate and assist, but the accident investigation is completely the responsibility of the NTSB, just as it is in the event of a maritime or aviation accident. As part of its task, the NTSB develops and issues a report at the conclusion of the investigation. The reports, which are available on the NTSB Web site, contain a series of appropriate recommendations to all parties, including the FRA but also other involved parties, such as railroad companies or railroad worker unions.

The second major office that is at the heart of FRA operations is the Office of Railroad Policy and Development. The Office of Railroad and Policy Development works directly to improve and maintain railroad operations. Its mission statement defines its operations as developing cohesive goals and policies for maintaining and improving the U.S. freight and passenger rail networks. A large part of its activities is supporting these efforts through managing the financial aspects (loans and grants) of these projects. In addition, the office conducts research and development in rail technology, draws up the rules for the methodologies for rail planning at all levels, and provides technical assistance for all parties (current and future) that will receive grants or loans.



The Federal Railroad Administration (FRA) performed this 2011 crash test in which a locomotive rammed into loaded hopper cars. The FRA is responsible for regulating the rail industry and for rail safety issues, but accidents are investigated by the independent National Transportation Safety Board.

It does this through the efforts of four subordinate organizations: the Office of Program Planning and Administration, the Office of Passenger and Freight Programs, the Office of Research and Development, and the Office of Policy. The Office of Program Planning and Administration is responsible for managing and supporting all efforts of the other three organizations. The Office of Passenger and Freight Programs is the financial branch of the office and manages grants and loans. The Office of Policy develops policies, makes policy recommendations, and also monitors developments throughout the industry. The FRA also supplies support and administers federal grants to Amtrak, which provides passenger rail service.

Northeast Corridor

While passenger service throughout the United States has declined over the past decades, in the stretch between Washington, D.C., and Boston, it is a high-profile operation. In addition to the major passenger service between those cities, the Northeast Corridor (NEC) also includes regional commuter lines, as well as rail lines that radiate out from the main line. In total, passenger service coupled with large freight operations results in traffic that exceeds over 2,000 trains a day. Because of the heavy amount of freight and the significance of the cities on the northeastern coast, the operation, maintenance, and projected improvement of the infrastructure is considered to be a major responsibility of the FRA.

While the refurbishment and continued enhancement of the Northeast Corridor has been an important part of FRA planning and operations, it was given a new urgency as a result of Hurricane Sandy, which struck the East Coast in 2012. In May 2013, DOT Secretary Ray LaHood announced that the FRA would provide (through the Disaster Appropriations Act of 2013) funding in the amount of \$30.2 million. Two-thirds of this amount is to reimburse Amtrak for expenses it incurred in removing debris and water as well as repairs to the infrastructural damage from the hurricane. The remainder of the funding is to be used to repair tunnels into and out of New York City that were damaged by the hurricane.

In April 2013 the FRA released the “NEC FUTURE Preliminary Alternatives” report, which presented 15 alternative plans (from a larger body of proposals) for development on the Northeast Corridor with the goal of meeting what it sees as

transportation needs in 2050. The 15 plans will be reviewed and a subset will be chosen. From that group, specific project(s) will be proposed for implementation.

The 15 plans are organized into four levels, grouped A to D, with A-level projects representing more modest objectives and D-level projects being significantly more ambitious. The first three alternatives are aimed at increasing service and capacity along existing Northeast Corridor main lines, mostly in the form of intercity commuter traffic and some intra-urban services. Level B has four alternatives, each of which is directed toward increasing service along the existing “spine” by decreasing the amount of travel time and increasing the number of trains. The third major set of options (Level C) aims to introduce an expansion of the existing main line with the intent of serving markets not previously served and increasing regional services.

The final level (D) is the most expensive, as it entails the construction of a second spine of Northeast Corridor infrastructure. One of the four proposals under discussion in this group is to construct a parallel line running the entire distance from Washington to Boston. The remaining three proposals call for a second line running parallel to segments of the total line. Analysts have also noted that there are two other options in addition to the 15 discussed in the report. One of these would be to adopt nothing in the way of enhancements; the other would be to adopt all 15 projects.

The criteria for judging the viability of the projects will be based, in part, on an FRA report titled “NEC FUTURE’s Preliminary Purpose and Needs.” These include maintenance to be continued on a level that ensures that existing infrastructure can meet future requirements, improves reliability of service, and the ability to meet passenger demand well into the 21st century. Other objectives identified in the report include environmental targets, improved rail capability in the region to assist economic growth, and reduction in energy use.

High-Speed Rail

High-speed rail has been at least discussed as a national program since the mid-1960s, the same time at which the FRA and the Department of Transportation came into existence. High-speed rail has had its champions, who often cite the Japanese “bullet train” or French high-speed railroads

as a model. The concept, however, has yet to win complete acceptance.

Some controversy exists around this program, as there is opposition to allocating public funds to this by those who are opposed to government subsidies for this type of project. In addition, there are some critics who maintain that funds would be better spent on reopening Amtrak lines that have been closed to cut costs, depriving regions of any access to Amtrak. Other critics have cited Amtrak lines (including those on the West Coast that already exist) that provide excellent service at significantly less than high-speed rail capability and that could benefit from infrastructure improvement.

Within a few months after beginning his first administration, President Barack Obama announced a renewed effort to make high-speed rail travel available to 80 percent of Americans. The objectives, as stated then, were to build new high-speed rail corridors, to upgrade existing intercity passenger rail corridors, and to create the basis for future high-speed rail services. Among the promised benefits, according to the FRA, high-speed rail programs would encourage regional economic growth, increase mobility and options for travelers, and decrease dependence on oil. High-speed rail efforts were incorporated into the American Recovery and Reinvestment Act of 2009. As of 2010, total funding was \$10.1 billion. Thus, high-speed rail has become a priority project within the FRA, at least for the present.

Similar Regulatory Agencies

An organization similar to the FRA is the European Union's European Railway Agency (ERA), which employs 100 people. In existence since 2004, ERA's mandate is to assist innovations to promote European rail competitiveness through compatibility and safety regulations. Another organization that performs a similar function is the Canadian Rail Safety Directorate. In the United Kingdom, the Office of Rail Regulation exists as a section reporting to the secretary of state for transport. It oversees adherence to safety and economic regulations by British railroads. Rail issues in Japan are managed by the Ministry of Transportation. India's Ministry of Railways is responsible for operation of Indian Railways.

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See Also: Deregulation; Freight Transport, Intermodal and Multimodal; High Speed Rail, Design and Technology of; International Rail Transit; Rail Corridor Congestion; Rail Transit Planning, U.S.; Railroads, Freight; Railroads, Passenger.

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Federal Transit Administration

The Federal Transit Administration (FTA) is an agency under the oversight of the U.S. Department of Transportation. The FTA provides assistance to urban transit systems throughout the United States through grant and loan programs that finance both capital expenditures and operating expenses and

ensures that recipient transit agencies are in compliance with federal and programmatic regulations.

While federal funds had occasionally been used to build transit infrastructure or maintain public transportation operations during President Franklin D. Roosevelt's administration (for example, the role of federal funds in building portions of subways in Chicago and New York), federal transportation policy during the post–World War II period focused primarily on building highways and encouraging the use of the private automobile. The Federal Aid Highway Act of 1956, signed by President Dwight Eisenhower, funding the nation's Interstate Highway System, was largely seen by critics as leading to the demise of urban mass transit agencies, causing them to close or reduce available services. As transit ridership declined due to the popularity of the private automobile and the massive federal investment in roads and highways, urban areas began to experience increased levels of traffic congestion, pollution, and physical and social isolation of nondrivers and those too poor to own a vehicle.

1960s

On June 30, 1961, President John F. Kennedy, recognizing the social and environmental implications of existing transportation policy, signed the Omnibus Housing Act, which, among other things, stated that mass transit is “a distinctly urban problem and one of the key factors in shaping community development.” Originally seen as a form of demonstration project to test whether there could be a worthwhile federal role in shaping and funding transit policy at the local metropolitan level, this act created an urban transit assistance program and placed it under the supervision of the U.S. Housing and Home Finance Administration (now known as the U.S. Department of Housing and Urban Development). The 1961 Omnibus Act provided \$25 million for grants and \$50 million for loans for pilot projects in mass transit, largely seen as a way to create transportation options for those too poor, young, old, or disabled to drive private vehicles.

President Kennedy continued to advocate a larger federal role in funding and shaping local transit policy because of its social implications. In 1962, President Kennedy's secretary of commerce and the housing and home finance administrator sent a letter to Congress advocating a “balanced” transportation system—one that did not overemphasize

car ownership to the detriment of public transportation—that could assist communities in land use planning, mitigation of traffic congestion, and provision of mobility options for nondrivers. The letter cited a decades-long cycle of service cuts and fare increases, which reduced the ability of transit agencies to provide services to low-income communities. The letter was seen as a significant lobbying effort to create new and continued programs of grants and loans for transit agencies.

President Kennedy, in a subsequent statement to Congress, said the following:

To conserve and enhance values in existing urban areas is essential. But at least as important are steps to promote economic efficiency and livability in areas of future development. Our national welfare therefore requires the provision of good urban transportation, with the properly balanced use of private vehicles and modern mass transport to help shape as well as serve urban growth.

After President Kennedy's assassination, Congress passed and President Lyndon B. Johnson subsequently signed the Urban Mass Transportation Act of 1964 on July 9, 1964. Originally proposed by President Kennedy, the Urban Mass Transportation Act of 1964 created the Urban Mass Transportation Administration (UMTA), which eventually became the FTA, and encouraged “the planning and establishment of areawide urban mass transportation systems needed for economical and desirable urban development.” By authorizing federal grants and loans for transit infrastructure and services, the act provided sources of additional revenue for the nation's transit agencies. Congress, however, did not authorize expenditures equivalent to President Kennedy's vision, appropriating less than \$150 million per year under the act.

In 1965, 1966, and 1967, various race-related riots occurred in major U.S. cities, including Los Angeles, Detroit, Chicago, and Newark (New Jersey). Occurring in majority–African American neighborhoods, the riots focused attention on the communities' sense of isolation because of inadequate transit availability. In the Los Angeles Watts neighborhood, for example, a bus ride to the County General Hospital took two hours each way; to reach the Youth Employment Training Center required

one hour and 45 minutes in each direction. Los Angeles's burgeoning freeways did little to assist Watts residents, largely too poor to own a private vehicle, with mobility challenges.

The National Advisory Commission on Civil Disorders, more popularly known as the Kerner Commission, was convened by President Johnson to investigate the causes of the riots and highlighted the inadequate transportation systems in many inner-city neighborhoods. Inadequate public transportation, the commission found, created hostility and was one factor precipitating the riots. The Kerner Commission's findings, as well as the perceived success of the grants and loans provided by the UMTA, led to the transfer of the UMTA to the Department of Transportation in 1968 and congressional passage of the Urban Mass Transportation Assistance Act of 1970. The act substantially increased funding of the UMTA—from \$150 million to \$500 million in 1972—and broadened the size and scope of loans and grants available to transit agencies.

The UMTA's *External Operating Manual* of 1970 clarified the goals of federal involvement in transit operations: providing transportation options to nondrivers, mitigating traffic congestion by providing mobility options to drivers, and positively impacting urban land use patterns and furthering environmental protection goals. Specifically, the manual stated, small metropolitan areas (those with less than 250,000 in population in 1970) should focus on enhancing transportation options to individuals lacking access to a private automobile. Mid-sized areas (between 250,000 and 1 million residents) should focus on reduction of traffic congestion. Large metropolitan areas (those with more than 1 million residents) should focus on improving land use and development patterns, presumably through the reduction of suburban sprawl. Thus, transit and transportation agencies across the United States were expected to promulgate the UMTA's goals in their applications for federal funds.

1970s and Beyond

The greater availability of federal funds to local transportation agencies through the Urban Mass Transportation Assistance Act of 1970 caused transportation planning to become a much more complex endeavor in the 1970s. Transit and transportation agencies receiving federal funds were required to collect and report data on a wide range of societal,



The Los Angeles Metro Gold Line light rail train, seen here at the Little Tokyo station on the opening day of its eastside extension on November 15, 2009, brought a new mass transit option to an area of the city that had long been underserved.

economic, and consumption impact metrics. The increased data reporting and collection requirements necessitated an increase in the administrative capacity and professionalism of agencies funded by the UMTA. The escalating complexity of transportation planning also formally linked transportation policy, and by implication the behavior of transportation agencies, with the social, natural, and business-related environment of U.S. cities—a reflection of President Kennedy's influence a decade earlier.

The Surface Transportation Assistance Act of 1982 was one example of the social impact of transportation planning and the role of Congress in determining both the UMTA's and local transit agencies' policies. This act required transit agencies to expand their services to include accessibility for all persons with disabilities; alternate transportation services, operating in the same geographic area and during the same times as general transit services, were required to be made available to anyone unable to use the system and at a comparable fare. While the act greatly expanded the availability of transit services for the disabled, it was an unfunded mandate. However, it specified that transit agencies were not

required to spend more than 3 percent of their operating budget on compliance with the act to avoid an excessive financial impact on transit agencies.

In 1991, Congress, in the Intermodal Surface Transportation Efficiency Act (ISTEA), Title III Federal Transit Act Amendments of 1991, renamed the UMTA the Federal Transit Administration (FTA). Congress and President George H. W. Bush sought a new name for the agency that better reflected its growing responsibilities, including provision of public transportation in rural areas and various transportation programs not technically considered “public.” The act further increased expenditures for the FTA to approximately \$5 billion a year, created new formula and discretionary grants, and established a transit planning and research program.

Programs and Administration

An administrator appointed by the president oversees the FTA and also reports to the secretary of transportation. The administrator oversees the 500 employees of the FTA and an annual budget of \$9 billion. In addition to its headquarters in Washington, D.C., the FTA maintains 10 regional offices in the metropolitan areas of Boston, New York, Philadelphia, Atlanta, Chicago, Fort Worth, Kansas City, Denver, San Francisco, and Seattle.

The FTA maintains two types of grant programs: discretionary and formula. Both types of grants were authorized by the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Examples of discretionary grants include Alternatives Analysis, Bus and Bus Facilities, Capital Investment Program, Clean Fuels Grant Program, National Research and Technology Program, Over-the-Road Bus Program, Transit in Parks Program, Public Transportation on Indian Reservations, Transportation Investment Generating Economic Recovery Program, and the Transit Cooperative Research Program. Formula grants administered by the FTA include Fixed Guideway Modernization, Job Access and Reverse Commute Program, Metropolitan and Statewide Planning, New Freedom Program, Rural Transit Assistance Program, Transportation for Elderly Persons and Persons with Disabilities, and Urbanized Area Formula Program. Each of the grants and programs require congressionally appropriated funding.

When a transit agency receives a grant from the FTA (as practically all do), it agrees to follow all federal regulations regarding public transportation and to report data to the FTA on various administrative elements like revenues, funds from other units of government, capital expenditures, operating costs, types of vehicles in use, ridership statistics, number and types of employees, energy usage, and on-time performance. It should be noted that transit agencies receiving federal funds are also required to report data on transit services that they contract out to the private sector.

While the role of the FTA in mitigating traffic congestion, urban air pollution, and suburban sprawl has arguably been mixed, the agency has played a large role in the provision and maintenance of existing transit agencies and infrastructure in the United States. By providing financial support to local agencies, the FTA is also able to oversee the actions and programs undertaken by local transit agencies, ensuring compliance with federal law and administrative constraints. The FTA also provides professional guidance to individual agencies with recommendations on areas including capital investment, transit finances, and transit-oriented development.

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See Also: American Public Transportation Association; Intermodal Surface Transportation Efficiency Act; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Surface Transportation Assistance Acts of 1978 and 1982; Transit Systems; Urban Mass Transit Act of 1964; Urban Mass Transportation Assistance Act of 1970; U.S. Department of Transportation.

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Federal Transportation Policy

Federal transportation policy encompasses the plans, programs, and actions taken by the federal government that are concerned with the movement of goods and people. In the United States, transportation policy takes place in an intergovernmental and multisectoral context, with the federal government playing an important role in ensuring coordination and collaboration. The federal government's primary role is to fund transportation infrastructure and regulate interstate and international commerce. Federal transportation policy has been characterized as fragmented and lacking a coherent overall national transportation policy. As the interstate system neared completion, passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) shifted federal transportation policy toward a more intermodal approach with greater flexibility for states and localities, marking a new, postinterstate era in federal policy.

Absence of National Transportation Policy

Despite creation of the federal Department of Transportation in 1966, the United States has not had a coherent overall national transportation policy. Transportation policy scholars point to the Transportation Act of 1940 as the first express transportation policy adopted by the federal government, with piecemeal additions and alterations made with each subsequent federal transportation legislation. John Coyle and his colleagues note that federal transportation policy is a composite of different federal legislations, rules, funding programs, and regulatory agencies, with the marked absence of a unified federal transportation policy statement or goal.

This fragmentation partly results from diverse interests and concerns driving federal transportation policy (such as interstate commerce, military preparedness, global competitiveness, and homeland security), which have resulted in multiple goals. The many (sometimes conflicting) policy goals include safe and efficient operations of multiple transportation modes; critical transportation infrastructure provision; regulation of private enterprise performing transportation functions; security of transportation facilities and operations; equitable access to transportation facilities across a

diverse population; and integration of transportation with concerns such as the environment, energy consumption, and economic development. Furthermore, the patchwork of ownership, funding, and operations for different modes of transportation across multiple sectors and levels of government further complicates national transportation policy.

Mode-Specific

Mode-specific policy has contributed to the fragmentation of federal transportation policy. Federal legislation usually considers water transport, rail, highways, air carriers, transit, and pipelines separately. Each mode has developed in a distinctive historical manner, and each has posed unique problems for policy makers and program managers.

While the modal approach is useful for organizing purposes (and the U.S. Department of Transportation is thus organized), it becomes problematic in terms of having a coherent national transportation policy because each mode does (and should) not operate separately from the others. Ports and airports need access to surface transportation for passengers and goods to travel without interruption. Addressing congestion requires that highways, transit, bicycle and pedestrian facilities, and commuter railroads fit together within the transportation network. Yet, pre-1990s federal policy was largely mode-specific and not integrative. More recently, following the passage of ISTEA, federal policy has become more intermodal, emphasizing the integration of various transportation modes into a single system.

Multi-Sectoral

The federal approach to transportation has also been multisectoral, relying on formal and informal public-private partnerships. Historically, the United States has relied on private enterprise for most transportation services, with the federal government furnishing and financing basic infrastructure (for example, roads, bridges, waterways, port facilities, airports) and regulating the private sector. This partnership characterizes air, highway, water, and, to some extent, rail transport. As early as the 1800s, the federal approach to transportation policy involved providing financial support to private transportation companies. First with private canals and then railroads, the government gave public subsidies, mostly as land charters or land grants, to companies to develop transportation facilities and

services expected to benefit the public. Later subsidies included direct federal cash assistance. However, as these private companies became more economically and politically powerful, federal policy took a more regulatory stance, using governmental power to push the private sector toward achieving public goals.

Beginning with the Interstate Commerce Act of 1887, federal regulatory agencies were established for tasks such as setting rates, licensing carriers, maintaining public safety, authorizing routes, and monitoring other permissible activities of private enterprise. However, these regulatory agencies tended to operate in “silos,” isolated from high-level policy leadership, making it difficult to pursue clear and coherent policy goals.

During Franklin D. Roosevelt’s administration, the regulatory approach was expanded to cover virtually all aspects of transportation. Aviation, the merchant marine, coastal shipping, trucking, and intercity bus services were all subject to regulation. While some argue that this regulatory policy has helped stabilize the country’s transportation system, critics say that the decentralized, legalistic regulation approach cannot deal with the complexity of transportation’s societal impacts and has hindered economic efficiency improvements needed to reduce transportation costs’ importance as a factor in production and personal travel. Beginning in the 1970s, the federal government’s regulatory stance softened, as evidenced by deregulation of the railroad, trucking, and aviation industries.

Intergovernmental

The federal government’s financing role is most dominant for surface transportation such as highways/roads and transit. States and localities have been the major implementers of federal transportation policy with federal financial assistance, owning and operating transportation facilities and playing key roles in transportation planning.

The automobile revolution raised the need to improve and expand the country’s road network. To create this national network, the federal government provided grants-in-aid to states and localities to financially support their capital investments. States and localities remained responsible for maintenance and ownership. This intergovernmental approach, cemented during the interstate-building era and institutionalized through the

federal-aid highway program, shaped contemporary federal policy.

Whereas the intergovernmental nature of the transportation program had been primarily federal–state, ISTEA introduced a federal–state–local transportation program by strengthening the role of metropolitan interests in transportation planning. It significantly enhanced state and local government officials’ power in surface transportation project selection. While many have argued that ISTEA represented a shift in attention from primarily one mode—highways—to other modes such as transit, others have suggested that it reflected a shift away from a federal emphasis toward the local and regional dimensions of transportation policy.

Conclusion

Despite fragmentation and challenges to coordination and collaboration, federal transportation policy has been a key player in nation-building efforts. Over the last 100 years, the federal role has shifted from the emphasis on providing rural post roads for getting produce to market, to connecting the nation’s centers of population, to addressing mobility and congestion problems, to promoting global competitiveness. Along this historical path, there have been varying emphases on defense and military preparedness, urban renewal, disaster relief, social equity, and homeland security.

ISTEA and subsequent federal legislation shifted federal transportation policy away from the broad focus on connectivity toward a set of goals for enhancing mobility, access, safety, environmental protection, and quality of life. Yet no clear organizing principle has replaced the Interstate Highway System as the rationale for federal policy. In addition, although the federal influence over transportation policy remains significant, the recent federal legislation (Moving Ahead for Progress in the 21st Century, or MAP-21) continues the emphasis (begun by ISTEA) of increasing the decision-making authority of state and local governments.

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See Also: Federal Aid Highway Program; Intermodal Surface Transportation Efficiency Act; Transportation Planning; Transportation Planning and Politics; Transportation Policies, North American.

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Ferries

Ferries are marine vessels that transport passengers, automobiles, freight, or some combination of the three over a river, lake, or other body of water. Ferries have traditionally provided a vital transportation link for people living near waterways. As early as the 17th century, ferry service was in operation in the Massachusetts Bay Colony. Ferry service was particularly important before advances in engineering made possible construction of permanent bridges and tunnels across bodies of water, and later it was used in many rural areas and in some urban areas to move commuters, business travelers, and tourists across waterways.

By the end of the 20th century, 134 million passengers were using ferries in the United States. Although the number of ferry passengers declined in the 21st century, ferries continued to be an important transportation service in the United States, particularly in coastal urban regions. In 2012, the National Census of Ferry Operators reported that 233 ferry operators in 36 states and two U.S. territories operated a fleet of almost 640 active vessels. Urban planners and security experts agree that ferries can continue to play a significant role in the nation's transportation system for the foreseeable future.

From Canoes to Fast Ferries

The first ferries in the United States were canoes. In May 1631, the General Court of the Massachusetts Bay Colony granted the right to operate a ferry between Winnisimmet and Boston. A rower for a few pennies transported a single passenger, allowing the passenger's horse to swim behind the canoe.

The ferry was a success. In 1712, legislation required a third boat be added to the fleet, and in 1749, additional legislation mandated that four boats operate for the transportation of passengers. Two of the boats were required to have sails in addition to oars; it also required two sober and able-bodied men to operate the boats and set operation hours. The Winnisimmet Ferry operated continuously until 1917. The Rocky Hill Ferry holds the record for the nation's oldest continuously operating ferry. From 1655 until its closing in 2011, the ferry transported passengers across the Connecticut River, privately operated for the first 260 years and operated by the state of Connecticut from 1915 until its closing.

The busiest ferry system in the United States traces its beginnings back to the 18th century, when it was run by private companies. It was not until 1905 that the City of New York took control of the Staten Island Ferry system. The first year of operation under the city's authority saw five new coal-burning steam ferries launched, each named for a borough of New York, and a nickel allowed a passenger to ride aboard one of them. In 1964, the year the Verrazano-Narrows Bridge linking Staten Island and Manhattan opened, 27.5 million passengers crossed New York Harbor on the Staten Island Ferry. The following year, the number had dropped by 5.5 million. In 2012, total ferry ridership was over 22 million. Another estimated 18 million passengers use private ferry operations.

The Staten Island Ferry may carry the most passengers, but Washington State holds the distinction of having the largest ferry system in the nation. Beginning in 1852 when the first boats of the famed Mosquito Fleet, so named because there were so many of them, filled the waters of Puget Sound, ferries have carried people and goods back and forth across the Sound. From those early days through the early 20th century, ferries were the major mode of transportation in a region where roads were poor where they existed at all.

So important were the ferries to Washingtonians that when finances forced the Puget Sound Navigation Company to tie up its boats after World War II, the state purchased most of the company's assets for \$5 million, and in 1951 the ferry system began operating under the authority of a newly created Washington Toll Bridge Authority, now known as Washington State Ferries (WSF). In the first year of operation as a state-operated system, approximately



The Jumbo Mark II Class ferry Wenatchee crosses Washington State's Puget Sound on a Seattle–Bainbridge Island route in 2007. The ferry can hold up to 2,500 people and over 200 cars at one time. Washington State has the largest ferry system in the United States. In 2012, the Washington State Ferries Authority carried more than 22 million passengers and 10 million vehicles on its 22 ferries.

4 million passengers rode the ferries. In 2012, WSF transported more than 22 million passengers and more than 10 million vehicles on 22 ferries. The system serves eight counties in Washington State and the province of British Columbia in Canada using 10 routes and 20 terminals.

In addition to Washington and New York, California, Louisiana, Massachusetts, New Jersey, North Carolina, Ohio, Texas, and Virginia all have ferry systems that typically carry over 1 million passengers annually. Hundreds of other ferry services, public and private, provide important transportation links in communities across the nation.

The upsurge in interest in ferries during the latter half of the 20th century was in part due to high-speed ferries. A 1999 Maritime Administration study reported that fast ferry ridership grew 6.8 percent per year from 1993 to 1997, even though only about 15 percent of 1,206 passenger ferries in the United States in 1997 were fast ferries. The catamaran, a twin-hulled vessel that offers speed, stability, and space, is the most common choice of fast

passenger ferry operators. With about one-third of U. S. ferries ready for replacement, the study predicted an increase in the number of fast ferries. Although the number did increase, the United States has been less eager than other parts of the world to utilize fast ferries, but growing traffic congestion and environmental concerns lead some experts to predict that will change.

Increased federal funding adds to the probability of more fast ferries. The Moving Ahead for Progress in the 21st Century Act (MAP-21), signed into law by President Barack Obama on July 6, 2012, extended the existing Ferry Boat Program, which had provided more than \$500 million to improve America's ferry boats and terminals in its 20-year history. New funding under MAP-21 brought the 2013 total to about \$64 million.

The Advantages of Ferries

Ferry services offer a less costly alternative to bridge and tunnel construction, a particular concern in urban areas with budgets stretched thin.

For example, the cost for the New Mississippi River Bridge connecting downtown St. Louis with southwestern Illinois was an estimated \$667 million, less than half of the original plan with a projected cost in excess of \$1 billion. In contrast, Washington State's *MV Chetzemoka*, pound for pound the most expensive ferry ever built in the United States at the time of its construction in 2010, cost \$80.1 million. Ferries can also relieve the morass created by securing rights-of-way for bridges, tunnels, and highways. Ferries that are part of urban transit systems are eligible for federal grants, just as highways and bridges are.

Traffic congestion, a major concern in urban areas, is often greatest at bridges and tunnels. Ferries provide an alternative to the transit buses and automobiles in such cases and generally reduce passenger work-trip times. Ferries are also a crucial element in urban security because they can be used to evacuate citizens and to bring in supplies and emergency or military personnel after land-side emergencies.

The best-known example of such use occurred after the terrorist attack in New York on September 11, 2001. On that day between 300,000 and 500,000 people, according to varying sources, were evacuated from Manhattan by water. But ferries had proven their effectiveness for evacuation earlier when they were used to move citizens out of the San Francisco Bay Area after the 1989 Loma Prieta earthquake. Operators of the free Galveston–Port Bolivar ferry consider preparedness for evacuation in the event of a hurricane one of their major responsibilities.

Environmental impacts of ferries include not only the emissions concerns shared with land vehicles but also wake wash, water discharges, and noise pollution. It is fair to say that some proponents have overstated the environmental advantages offered by ferries. Diesel-powered ferries without emissions controls produce more nitrogen oxides but less carbon monoxide per passenger trip than does a car. Environmental activists in the San Francisco Bay Area and in New York have protested ferry systems that failed to fulfill their claims of significantly reducing air pollution, and the Hawai'i State Supreme Court effectively stopped the operation of that state's Superferry in 2009 when it struck down an act passed by the legislature that exempted the ferry's operator, Hawai'i Superferry, Inc., from

carrying out an environmental impact study. But the consensus is that when proper technology is used, ferry systems sometimes decrease emissions and almost certainly will not add to the existing air pollution load. Wake wash, a primary environmental issue with ferries, is manageable with proper implementation and oversight.

Concern about safety has increased with the expansion of ferry services, with vessel instability and insufficient fire protection being paramount. Ferry accidents garner headlines and raise public concerns, but ferries in the United States have an enviable safety record. From 2000 to 2010 the national average of fatalities due to ferry vessel operations was fewer than two fatalities per year.

According to the National Census of Ferry Operators, ferries in the United States provide commuter services in major metropolitan areas on both coasts, offer an essential intercity transportation link between coastal Alaska communities and the lower 48 states, and link roadways and communities separated by various bodies of water. The role of ferries in the U.S. transportation system is a vital one that seems likely to increase in importance.

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See Also: Bridges; Harbors and Ports, Administration and Operations of; Inland Waterways, Passenger Traffic and; Maritime Transport; Nitrogen Oxides; Ocean Passenger Travel; Ships.

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Fiscal Politics

Most of politics is about money and most of the rest is about jobs. Money has been described as the “mother’s milk of politics,” or, as one definition of politics puts it, politics is about who gets what, when, and how. Transportation fiscal politics is about who, what, when, and where money for transportation needs and projects will be spent.

Many political supporters of candidates and political parties are into politics for the money. That is, they support a candidate in order to gain jobs, contracts, or other interests. Historically, in the United States, the spoils system grew greatly under President Andrew Jackson. It peaked with the assassination of President James A. Garfield by a disgruntled federal office seeker. Thereafter the civil service reduced the number of political appointees. However, in both federal and state governments, many jobs and appointed offices remained for supporters.

U.S. Transportation Funding History

Since the beginning of the republic the Congress has authorized many billions of dollars for transportation needs. Early in its history, the Corps of Engineers was paid to clear snags from the rivers that were used as major transportation arteries. Canal building was financed by a combination of private and public monies. All too often the complaints about wasting public money on canals in the service of private interests was based in fact, as friends were rewarded with contracts that they fulfilled poorly, or bad decisions were made for partisan reasons. The large stone bridge in the Erie Canal, for example, did not last long because porous local sandstone was used against the advice of engineers.

Many railroads were financed by a checkerboard pattern of land grants. The federal government moved alternating square miles of land on either side of the new railroad tracks from public domain into the hands of the railroad company building the tracks in order to finance the line. The government then sold its remaining share of land in order to promote development.

Many transportation projects were opportunities for boondoggles that wasted money on bridges to nowhere or canals or roads that were not used enough to repay their costs in terms of economic benefits. Transportation projects have often been sources of pork barrel politics as legislators, whether

state or federal, sought to bring to their home district money that would be spent on roads, bridges, or other transportation projects, whether needed or not. The politics of pork barrel projects is usually “log rolling” for votes in which legislators or members of Congress cooperate to vote for each other’s spending desires without regard to the public’s interests. The money then spent in the home district is viewed as a sign of political success. Politicians who fail to get pork barrel projects do not last long in office.

The advent of automobiles soon led to the adoption of appropriations for the building of federal highways. The Federal Aid Road Act of 1916 (Bankhead-Shackleford Act) set in place a pattern of federal project grants following a matching funding formula. The road standards were to be set by the American Association of State Highway and Transportation Officials (AASHTO). The bill was signed by President Woodrow Wilson, who was an advocate of good roads as a stimulus to the development of the country.

The funding required that the roads be open to the public for use free of charge. Rural road-building plans of the states were to be submitted to the secretary of agriculture for approval before the funds were spent. Consequently, farmers were interested in good farm-to-market roads and in Rural Free Delivery by the Postal Service. The Supreme Court’s decision that the commerce clause (Article I, Section 8) permitted Congress to spend money on interstate roads aided the politics of those seeking government spending for roads. In 1917 it became necessary for every state to have its own highway department in order to administer road-building money.

The Federal Aid Highway Act of 1921 was adopted in order to develop the immense national road system through the Federal Aid Road Program. Programs were administered by a growing number of agencies, such as the Office of Road Inquiry, Office of Public Roads, and the Bureau of Public Roads. These were included in 1966 in the Federal Highway Administration (FHWA), which is a division of the U.S. Department of Transportation.

Interest Groups and Funding

Competing for roads for transportation dollars are canals, river barges, harbors for oceanic shipping, airports, and public transportation systems of buses and railroads. Every form of transportation serves

some set of interests. These interests may be individuals who want transportation to be available and affordable; various interest groups, including environmentalists, bicyclists, labor unions seeking jobs on public projects, business interests seeking contracts for road work, or other associated benefits; politicians; and even government agencies that will administer the money. However, the supply of money is finite and the transportation interests are extensively varied and often competitive. Barges, railroads, and trucking firms compete as freight haulers. They also compete politically by supporting allied groups or business interests in order to secure funding.

Fiscal policies are used to tax and spend for public purposes. Taxation and fees are used to pay for and promote public interests. Spending is allocated to achieve specific policy goals. The political issues between groups competing for transportation subsidies or appropriations involve which kind of tax is levied, who pays it, and who will spend the money. For example, federal and state gasoline taxes are used to pay for highways. The rate of taxation is uniform for the federal tax across the whole of the United States, but tax on fuels varies from state to state as each is free to collect according to its specific needs. Regardless, the tax affects the cost of doing business for taxicabs, truckers, bus companies, and people whose work involves significant amounts of driving. The fuel taxes are used to pay for highways with specific sums allocated to highway contractors.

Every state has a highway department that is organized to reflect the politics of that state. In some the representatives on the highway department board are appointed by the governor and the legislature by congressional district. The goal is to facilitate the politics of the highway funds. The exchange of political support for the various parties is crucial for success but also a source of conflict at times with the public interest, as private interests may be more successful in gaining the support of politicians eager for political support at election time.

Some states follow a pay-as-you-go fiscal policy, which keeps borrowing limited. Other states have been open to borrowing for transportation projects and are practicing an expansionist fiscal policy.

The “Highway Lobby”

Building and maintaining road systems requires funding an ongoing series of construction projects.

Tremendous sums are expended annually by local, state, and federal governments to fund road builders. In the United States almost all roads are built by private companies that are funded by public monies. As a consequence, the competition to get the contracts to build or repair roads is intense. Lobbyists are those who seek to influence government agents, whether from legislative or executive branches of government, to build or to choose their clients.

The “highway lobby” (also known as the “road gang”) is a collection of automobile and truck manufacturers, tire makers, auto parts companies, trucking companies, oil producers and distributors, paving companies, allied companies and their trade associations, and two major lobbying organizations. Allied companies would be those like Dow Chemical, which manufactures automobile and truck cleaning supplies. The highway lobby has been able to dominate ground transportation since the beginning of the 1930s and the great expansion of the highway system.

Funds for the federal highways, both interstates and federal highways, have come from the 1956 Highway Revenue Act, which established the Highway Trust Fund. Prior to the establishment of the Highway Trust Fund financing for federal roads came from the General Fund of the U.S. Treasury. The monies for the Highway Trust Fund first came from a federal tax on gasoline sales, and the supplemental funds could be added from the General Fund of the U.S. Treasury. Since 1956, when the gasoline tax was 3 cents per gallon, the tax has been increased to 9 cents under the Surface Transportation Assistance Act (1982), and then to 14 cents per gallon by the Omnibus Budget Reconciliation Act of 1990. The Omnibus Budget Reconciliation Act of 1993 raised the tax to 18.4 cents per gallon, but all of the money went for deficit reduction and not into the Highway Trust Fund.

The Taxpayer Relief Act of 1997 redirected the 18.4-cent tax to the Trust Fund. Funding was allocated for six-year periods. Currently the Trust Fund is inadequate to meet the costs for highway maintenance and new construction. Tax receipts in the Trust Fund have recently been declining as the use of hybrid and other fuel saving vehicles are used on the nation’s roads. One proposed solution now being tested is the installation of a mileage meter, which would record the miles driven and then

charge drivers in accordance with their mileage. This “user fee” would be a regressive tax and would generate large sums for the Trust Fund.

The leading lobbyist organizations for the Highway Lobby are the American Highway Users Alliance and the American Road and Transportation Builders Association (ARTBA). The American Highway Users Alliance (AHUA) was founded in 1932 by General Motors and other organizations. It was merged with the Automobile Safety Foundation and with the Auto Industries Highway Safety Committee in 1970. It is a nonprofit interest group representing the automobile and road construction industries that publishes research on highway construction, safety, and funding. It lobbies on issues involving highway funding, construction, and safety, and is an advocate for the position that all gasoline taxes should be used for road construction alone. Other interests have sought to divert money from the Highway Trust Fund to other projects, including railway transportation and budget deficit reductions.

The AHUA claims to have been a successful advocate for road construction by the federal government since the 1930s. Its reasons for increasing highway construction have changed over the years. With climate change, oil prices and congestion being discussed as major public concerns, the AHUA advocates increasing highway construction in order to reduce greenhouse gases and improve the economics and safety of ground transportation.

ARTBA is a lobbying organization founded in 1902 and based in Washington, D.C. It is an advocate for road construction with over 5,000 members. Its members study ground transportation infrastructure needs and then advocate for construction funding for projects that will meet these needs.

Opposition to the highway lobby grew significantly after activists were successful in preventing supersonic jet liners from landing and taking off at airports in the United States. Joining with environmentalists and advocates for alternate forms of transportation, especially rail transportation, this opposition formed the Highway Action Coalition. Since the 1970s various groups opposed to the highway lobby have been able to block projects or to divert funds from the Highway Trust Fund to rail projects.

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See Also: Federal Aid Highway Program; Federal Transportation Policy; Highway Finance; Highway Trust Fund; Transportation, Economics of.

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FreedomCAR and Vehicle Technologies Program

The FreedomCAR and Vehicle Technologies (FCVT) Program is a research initiative between the U.S. government and the nation’s automotive and energy industries. It was initiated in 2002 as a successor to the Partnership for a New Generation of Vehicles (PNGV) program, which was a partnership between the U.S. Department of Energy (DOE) and the U.S. Council for Automotive Research (USCAR), made up of DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation. The same players formed FreedomCAR—with CAR standing for Cooperative Automotive Research—to further develop technologies that would reduce fuel dependence and engine emissions in U.S. passenger vehicles and light trucks.

In September 2003, the program expanded to address issues related to fuel infrastructure by adding five new members representing key participants in the U.S. energy industry: BP America, Chevron Corporation, ConocoPhillips, ExxonMobil Corporation, and Shell Hydrogen (U.S.). The expanded initiative was renamed the FreedomCAR and Fuel Partnership. Two electric utility companies, DTE Energy in Detroit and Southern California

Edison, joined the partnership in 2008 to help with FreedomCAR's work related to interface and infrastructure issues involving electric vehicle technologies. All the members work together to share resources and devise options for underlying technologies and processes designed to support the initiative's target goals.

The FreedomCAR and Fuel Partnership is focused in the short term on supporting technological research and development of battery-electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Its longer term strategic goal is the development of technologies for hydrogen-powered fuel cell vehicles that are not dependent on petroleum and do not generate harmful emissions or greenhouse gases. Like its predecessor, the new partnership seeks to achieve its technology goals while maintaining desired automotive attributes for consumer comfort and mobility.

The partnership's approach involves early focus on more fuel-efficient internal combustion engines and hybrid electric vehicles, as well as the potential use of all-electric vehicles and biofueled internal combustion engines. The group aims ultimately to develop an infrastructure for supplying hydrogen fuel for fuel cell powered vehicles. To address the technical challenges associated with the planned research and development pathway, the initiative has established quantitative technology and cost targets through 2015 in eight areas. The technology targets hone in on these areas: basic combustion and emission control for internal combustion engines, fuel cell power systems, fuel cells, hydrogen storage systems, energy storage systems for hybrid vehicles, hydrogen production and delivery systems, electric propulsion systems, and materials for lightweight vehicles.

Structure of the Partnership

The FreedomCAR and Fuel Partnership comprises several oversight groups and technical teams. The Executive Steering Group is responsible for the program's governance and includes the DOE assistant secretary for the Office of Energy Efficiency and Renewable Energy (EERE) and a vice-president-level executive from each of the partnership's member companies. The FreedomCAR Operations Group is driven by DOE program managers and USCAR company directors. It is charged with directing the partnership's technical teams

and prioritizing its research issues. The Fuel Operations Group comprises DOE program managers and directors of the member energy companies and has oversight of the FreedomCAR technical fuel teams. The Utility Operations Group was added to the organization in 2009, led by DTE Energy and Southern California Edison, to address coordination between electric-based vehicle technology and electric utility infrastructure.

The organization is also divided into operational technical teams that establish specific technical and cost targets and direct research and development in the areas of appropriate candidate subsystems. Each team creates research and development plans and roadmaps, reviews research results, and evaluates technical progress toward meeting stated research goals. The majority of the technical teams are centered on a designated technology, such as fuel cells or electric grid interaction, but some work collaboratively across all technical teams to ensure consistency. Examples of interdisciplinary teams include those working on codes and standards and systems analysis of vehicles. Each technical team generally includes DOE technology development managers as well as scientists and engineers with technology-specific expertise from the USCAR member companies, energy and utility partners, and national laboratories. Within the DOE, primary responsibility for the FreedomCAR and Fuel Partnership falls under two EERE offices: Vehicle Technologies and Fuel Cell Technologies.

Technical Areas of Research

The FreedomCAR and Fuel Partnership continues to research and develop technologies aimed at delivering fuel-independent, low-emission vehicles that offer freedom of both choice and mobility for U.S. consumers.

The partnership is investigating all aspects of advanced internal combustion engine operations and emission controls. Efficiency enhancements have been achieved and additional research is being conducted in the areas of combustion, emission, and kinetics of fuel derived from biomass. Specifically, work is aimed at understanding the underlying changes that occur in ignition and emission-formation processes when different compounds found in biofuels are used in the engine.

Fuel cell technology is a key area of the partnership's research because, along with the hydrogen

fuel they would consume, fuel cells offer the promise of zero emissions, high efficiency, and smooth, quiet operation associated with an electric propulsion system. The research and development efforts in this area have led to significant progress regarding performance increases and cost declines, but nothing as of early 2013 that was ready to compete directly with conventional systems.

Onboard hydrogen storage as an enabler for fuel cell powered vehicles is another key target. The goal is to cultivate the development and demonstration of commercially viable hydrogen storage technologies for both transportation and stationary applications. An explicit objective of the program is to achieve a vehicle driving range of more than 300 miles between refueling stops while at the same time meeting vehicle packaging, weight, cost, and performance requirements. The onboard hydrogen storage research also includes life cycle issues, energy efficiencies, safety, and environmental impact.

The partnership is looking into improving electrochemical energy storage technologies as well, especially high-energy batteries and ultracapacitors. Significant improvement in their performance could result in greater electrification to power BEVs and PHEVs. Lithium-ion battery technologies have been a particular area of promise for achieving high power, energy, and other performance requirements for electric vehicles at lower costs than other battery systems.

In the area of electric propulsion and electrical systems, the partnership has focused on key pre-competitive technical targets, such as packaging, cooling, materials, and devices, which can be designed to help achieve long-term reductions in volume, weight, and cost. Similar goals are set for structural materials, where some progress has been demonstrated in the area of magnesium powertrain components.

Teams under the fuel cell technologies office are addressing fuel pathway integration, hydrogen production, and hydrogen delivery issues to identify needs and gaps regarding short- and long-term production and distribution of hydrogen for transportation purposes. Biofuels distribution is also on the partnership's research agenda.

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See Also: Alternative Fuels; Automobile Design; Automobile Emissions Controls; Automobile Engines; Carbon Dioxide Emissions; Carbon Monoxide Emissions; Emerging Technologies; Environmental Impacts; Green Transportation; Hybrid Automobiles/ Hybrid Electric Vehicles; Hydrogen Fuel Cells; Light Electric Vehicles; National Ambient Air Quality Standards; Partnership for a New Generation of Vehicles; Smart Cars.

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Freight Handling

Ever since Roman times, trade flows have relied on the development of new transport infrastructures. Famous routes have included the Mare Nostrum or the Great East Road with its jade and silk routes, and later, those connecting the medieval fairs of Flanders, Lombardia, the Hanse, and the Ile-de-France region. The revival of the Mediterranean basin and the discovery of the New World further accelerated those trends. While these developments have strongly rested upon the work of those in charge of transport operations, the workers who handle and shift the freight to be stocked or delivered have played an equally important role. Ship suppliers, dockworkers, dock laborers, and longshoremen in the United States; stevedores in Great Britain; wharfies in Australia; timber rafters on the Lumber River in North Carolina; permanent packers and casual meat porters at the Paris Central Food Market; hucksters, street sellers, four-season merchants, and rag-and-bone men in the United Kingdom; junkmen in the United States; and warehouse

assistants all over the industrialized world—all have been (or still are) the backbone of the freight chain.

Throughout the 19th and 20th centuries, the emergence of major infrastructures around the globe—for example, the Pacific and Missouri Pacific Railroads, the St. Louis–San Francisco Railway, the Suez and Panama Canals, the Trans-Siberian, the Jingbao Railway, the U.S. interstate routes and Golden Gate Bridge, the railway connecting Zouerate to Nouadhibou in Mauritania, the Mont Blanc, Seikan, and Channel Tunnels, or the Pearl Bridge in Japan—was closely followed by the expansion and diversification of transport modes.

Until the invention of the shipping container by Malcolm MacLean in 1956, the transfer of goods required some significant physical activity. When the crate containing the goods was separated from the truck trailer frame, and when merchant ships were tailored to transport the freight, packaging became standardized, which led to the development of intermodal transport and the industrialization of port operations.

Following this short historical reminder, this article now turns to the numerous tasks performed by freight agents in the haulage and logistics sectors. This is followed by a focus on the organization of handling activities with especial attention to the constraints and enabling factors, including details about the tools and equipment commonly used by agents. The final section on the intensification of work and its consequences ends with an attempt to briefly outline future perspectives.

Occupations

In the United States, according to the Bureau of Labor Statistics, freight handling falls within the transportation and material moving occupations sector, which includes two categories: (1) hand laborers and material movers (3,315,400 in 2010) and (2) material-moving machine operators, including construction and transportation (669,000 in 2010). Even though they are not recorded as such, delivery truck drivers and driver/sales workers (1,262,600 in 2010), together with heavy and tractor-trailer truck drivers (1,604,800 in 2010) also undertake freight-handling duties as part of their work. This group of workers also includes maintenance technicians, handling engineers, and logistics-related staff (logistics coordinators, order assistants, etc.) in charge of finalizing the distribution of freight.

Freight handling includes the loading and unloading of vehicles in a wide range of settings: transportation scheduled and air courier terminals; ports; platforms supported by e-commerce (trucking and courier, parcel delivery services); combined railroad, waterways-road, or multimodal water-road-rail platforms; and product supply and household delivery services.

In all these modes, workers handle manufactured goods or bulk materials (raw food such as grains or building materials such as gravel, sand, and wood, and even garbage in some instances). In the case of bulk handling, goods are either solid or liquid and remain unpackaged or undocked. Manufactured products may be packaged or placed on pallets or in containers. “Heavy parcels” (engines, turbines, rockets, etc.), which constitute exceptional freight, are kept separate.

Operations and Handling

Depending on the platform from which they handle the freight, agents may undertake a variety of operations, such as container stuffing, stowing, loading, unloading, transshipment, stacking, degrouping (that is, container emptying), and preparing the distribution. Even if the containers require some checks, as well as cleaning and maintenance, many intermediary tasks have disappeared as freight from different shippers is now generally combined in one single shipment.

Freight handling may occur either at the beginning or the end of the supply chain, or between several transport modes or shuttles. However, it always occurs when the load reaches its breaking point in the transport chain. Agents working at the terminals of major exchange routes tend to handle mainly bulk or containers, whereas those working on end-of-circuit platforms are most likely to handle parcels. In any case, agents’ performance is measured against the flow of traffic in these nodes of the transport network.

Their activity is constrained by two factors. First, the volumes to handle vary significantly over time, and unless the means of production are adjusted, the operations may cease to be profitable. These operations are already under strain because they require significant investments (particularly on terminals) and also because they are subjected to important locational competition. Moreover, the operational planning prepared on the day preceding arrivals does

not make it possible to deal with all the events that may jeopardize the smooth running of the system.

Second, next to dysfunctions intrinsic to operations, handling is exposed to the same hazards as the transport modes (density of traffic, mechanical problems, deteriorated infrastructures, bad weather conditions, etc.). The agents' performance is therefore also affected by external factors. A particular challenge, then, is to ensure that the site does not get overloaded and that waiting times are kept to a minimum. The production system thus crucially needs to be reactive and adaptable.

The system's ability to adjust mainly depends on the means of production and on its labor force. Before the container revolution, the organization of production used to rely on temporary piece workers (particularly for unskilled jobs) so as to adjust capacity to demand. Hence, to be hired, dockworkers, longshoremen, stevedores, and wharfies had to wait for the ships to arrive. Even today, many handling operators employed on parcel services platforms or in warehouses are hired a few days before or on the eve of the freight's being delivered. When specialist skills are required (that is, for reach stacker drivers, crane operators, or container crane operators), it is not always possible to rely on temporary staff. In case of late arrivals or unusually high freight volumes, permanent agents may be called upon unexpectedly. Agents' ability to use multiple skills allows the system to adjust. In many inland ports, agents can be assigned to different positions (container crane, reach stacker), tasks (freight handling, container cleaning, checks and approvals), or sites for a day, half a day or even a few hours. The agent may also be assigned to a different time slot than his usual one.

Thanks to multitasking, the task of supervising production can be shared among foremen and frontline operators (team or quay managers). This arrangement is vital given that the dynamics of the situation result from a combination of what happens on the site and in the local vicinity, the temporalities of the various processes (shipping mode and handling operations), and the vagaries of the transport chain. Inversely, foremen may occasionally carry out handling operations to relieve frontline operators of a heavy workload.

The tools used for handling are determined by the environment, the goods, and their packaging. Agents are specialized accordingly. On container or

bulk terminals, crane operators may be in charge of steering fixed or mobile container cranes or gantries under the foreman's supervision through a system of shared information. Forklift truck operators use mobile quayside container cranes, straddle carriers to pick up the containers, or reach stackers to lift them up. Driving or moving on the site without causing undue risks for people or goods requires a skillful mastery of the equipment, which can only be acquired after a long training period.

Delivery

If we now turn to parcel delivery services, depending on the level of package standardization, two types of platforms can be distinguished: nonuniform and standardized.

Unless processes are standardized, agents have to handle a great variety of parcels in terms of length, volume, and weight. In addition, there may be varying levels of fragility, value, or danger. Since incoming goods are rarely grouped, agents are required to prepare pallets. Inversely, they may be asked to "de-palletize" the freight when the existing pallet has become deteriorated. Thus, there is still a certain degree of manual handling and stacking. Handling agents commonly use rolling equipment such as sack trucks or dollies. But most of the time, they use pallet trucks for horizontal handling on more important distances between different spans. Forklift and stacking trucks allow both horizontal and vertical handling. The second type of parcel service concerns express delivery, in which parcels are standardized. A conveyor belt reduces the need for agents to constantly move around. In some cases, it may lead to task automation (hence to job losses).

Even if there is still much paperwork to deal with (loading sheets, train composition, orders), the transfer of information has undergone a significant evolution with the introduction of information systems. Unless the goods are recorded upon their receipt, the risk of their going astray is high. The recording is done through a scan when the systems of each agent (loader, carrier, and handling agent) are compatible. One of the most noteworthy changes is the use of voice picking at the end of the supply chain, which allows the warehouse order assistants to receive the instructions from the information system itself. As his approvals go through, the agent obtains the code, the quantity, and the localization of the goods to be prepared on his cart. Through a screen installed in

his reach stacker, the operator receives similar information about the containers.

Risks

The global economy has led to an increasing use of just-in-time and intermodal operations, thus multiplying ruptures in the supply chain. This prevailing trend in the production system reduces time adjustment margins in case of unexpected events. Today, information systems increasingly facilitate the identification and traceability of goods. The capacity to control the system is much higher, jobs require much more sophisticated skills, and recovery times are lower. The combination of all these factors leads to an intensification of work.

For all the modes, handling the vehicles immediately upon their arrival or seeking to reduce waiting times is particularly important when the cost of immobility is high, as is the case for cargo ships. Consequently, agents have to work on irregular or staggered shifts. Their work also entails significant physical efforts (recurring heavy workloads, painful postures) and exposure to a range of environmental factors (for example, important heat variations, bad weather conditions when working outside, engine noises and vibrations, and toxic products, particularly when handling bulk material). The prolonged exposure to these harmful factors leads to many long-term health risks such as musculoskeletal disorders and occupational diseases such as cancers.

In addition to these long-term health risks, significant accidents can occur on the platforms used for handling activity. This is because there are conflicts over the usage and sharing of space. With the exception of automated chains, the platforms are characterized by numerous vehicle movements. Even if most of the time there are traffic schedules, the vehicles can cross over or encounter pedestrians. Visibility is limited because of how space is laid out, with merchandise being piled up and hiding machinery or agents.

Vehicles and machinery often collide or fall over during checks or installation of twistlocks. Moreover, slips are frequent because of leaks. In the case of hand operations, the mishandling of merchandise can cause sprains. The portage or falling over of parcels can cause lower back injuries and vertebral compression fractures. More generally speaking, objects falling down or spatters can sometimes lead to work incapacity.



Military personnel transfer cargo from a support ship to the USS Dwight D. Eisenhower aircraft carrier in the Persian Gulf, April 5, 2007. Hands-on cargo handling like this has a high potential for injury and long-term health risks.

Automation

Despite the slowdown due to the worldwide economic crisis that started in 2008, the global traffic of containers keeps on growing. Private operators are thus tempted to automate a great part of their handling operations so as to increase the processing capacity of operations outside normal business hours. Irrespective of the mode and container being used, new automatic handling systems (automated stacking cranes, automated guided vehicles, automatic postal parcel turning machines) have appeared. These systems are adapted to standardized operations both with regard to merchandise (parcels or containers) and signage (that is, shared

data sheets and information systems). Yet they require human intervention whenever the situation differs from what is expected because of problems such as failing or erroneous information, damaged parcels, twistlock deficiencies, or overloads, as is often the case in transport systems.

Such contingencies are unlikely to disappear in the foreseeable future, notably because of the growing significance of e-commerce. Consequently, attempting to supersede the human factor through machinery would be highly damaging for freight handling and hence for the transport system at large. The interaction between human agents and their environment will thus remain a subject of scrutiny for academics and practitioners alike.

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See Also: Containerization/Container Shipping; E-Shopping; Freight Terminals; Intermodal Freight Transport, Technology and; Just-In-Time Systems.

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domains. The “tariffs,” fees, and/or taxes were added to the price of the goods. In this sense, a tariff is a tax. Tariffs were used in the United States during most of the 19th century in order to protect American industries from foreign competition and to finance the federal government.

Transporting goods is expensive so transporters developed systems for pricing the cost of shipping cargo. Their charges for transporting would be the tariff or the freight rate on land or the freight on board a ship. Whether by land or by sea, the tariff or freight rates depended upon the kind of cargo and its destination. Shippers priced the cost of carrying the cargo or freight in terms of its type, its weight, its distance to its delivery destination, any transit services, and other factors. For example, the tariff or freight rate for shipping animals would include the cost of passage on a train or a ship as well as the cost of keeping the livestock supplied during a voyage. In many times and places, shippers were able to set their own freight rates. The table of charges set by a railroad, bus line, trucking line, airline, barge operator, or oceanic shipper would be its bill or cost or charge or tariff.

In modern times, freight rates have continued to reflect the destination as well as the type of transportation (train, truck, ship, bus, aircraft) because the costs vary, often in relation to the speed of delivery. So shipping by air is generally more expensive but worth the cost for perishable goods or for timely delivery.

In competitive shipping markets freight rates are set competitively by different companies. In competitive markets, entry to providing shipping is usually very open to newcomers. However, in many modern markets governments have intervened for political reasons. In these regulated market situations, the freight rates are set by government agencies in order to protect politically active interests from “excessive” charges. However, it has been common for the regulated transportation market to then be closed, with a government-controlled monopoly or oligopoly providing shipping. The closed market is then protected from competition to the benefit of the operators but usually to the financial detriment of the consumer public.

In the 19th century in the United States, railroad companies set their own freight rates at first. However, abusive practices soon entangled them in politics with people and business interests hurt by the

Freight Rates/Tariffs

Goods or produce that are not consumed locally may be transported for short or long distances in order to supply markets. Seeking commercial gain from the transportation of cargo or freight, whether by land or sea, has been a business activity pursued since prehistoric times on the Silk Road, the Grand Trunk Road, or any other trade route.

From ancient times, tolls were charged by governments on the goods that traveled through their

railroad freight rates. Frank Norris published *The Octopus* (1901) as a muckraking novel about the struggle between wheat growers in California and the Southern Pacific Railroad. The wheat farmers were victimized by the unwarranted rate hikes of the railroad. The railroads felt they should charge “all the traffic would bear.” This business practice was viewed as excessive by those seeking to use the railroads for shipping. In fact, it was within the limits of what customers would pay without seeking an alternative form of transportation.

Passions against railroad companies mounted soon after completion of the transcontinental railroad. As farmers grew crops, they needed the trains to ship wheat and other crops to markets but were enraged at what they believed were unscrupulous freight rates. The farmers movement between 1867 and 1896 spawned the Grange (Order of the Patrons of Husbandry), Populists, and other organizations that were successful in generating popular support for controlling the railroads, grain elevators, and other businesses that were viewed as harmful to farmers and small businesses. Legislatures and the Congress created rate-setting agencies to prevent rate gouging.

Starting in the 1870s, the railroad owners who opposed regulation sought help from federal judges and the emerging substantive due process doctrine. For the last third of the 19th century railroad cases dominated the Supreme Court’s docket. In *Munn v. Illinois* (1876) the Supreme Court allowed states to regulate grain elevator rates and intrastate freight rates. The *Munn* decision was weakened by the Supreme Court’s decision in *Wabash, St. Louis, and Pacific Railroad Company v. Illinois* (1886) in that the court restrained the power of the states to regulate interstate rates. The case stimulated the creation of the Interstate Commerce Commission (ICC).

The Interstate Commerce Act of 1887 sought to regulate the railroad industry and its business practices. The act mandated that railroad rates had to be “reasonable and just”; however, it did not empower the government to set specific rates. The act also mandated that the railroads publicize shipping rates. Differentiation between short-haul and long-haul rate fares was forbidden as a form of price discrimination against farmers and small markets. The act also created the Interstate Commerce Commission (ICC) to serve as a regulatory agency.

The ICC was a weak regulator at first because it lacked enforcement powers and because the Supreme Court interpreted its powers as limited in the light of its probusiness doctrine. During the administration of President Theodore Roosevelt changes were made. The Hepburn Act (1906) began the expansion of the ICC from railroads to all common carriers except airplanes. The ICC was also granted powers to deal with labor disputes and consolidation in the 1950s and 1960s.

In 1966 the safety functions of the ICC were transferred to the Department of Transportation. In the 1980s the deregulation movement led to the reduction of ICC supervision of rates. In 1980, passage of the Staggers Rail Act and the Motor Carriers Act further limited its powers. In 1994 the ICC was terminated and its remaining regulatory functions were transferred to the National Surface Transportation Board.

States were also active in regulating freight rates. In Texas the Railroad Commission was at first assigned the responsibility to regulate railroads, but it was later assigned responsibilities for regulating the new booming oil industry.

Other states also regulated freight rates. They called their respective regulatory agencies by different names. As the states sought to regulate the operation of transporters within their states, the variance inspired the railroads to appeal to the federal government, where a less heavy regulatory hand could be found. States could regulate in the public interest but had to do so in a manner that respected the property rights of the shippers.

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See Also: Deregulation; International Customs and Duties; Interstate Commerce Commission.

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Freight Terminals

Freight terminals are transportation nodes where freight or cargo is loaded or unloaded. Most freight terminals are located at ports and are intermodal, meaning that they process more than one mode of transportation—the simplest form, for instance, would be a terminal at a port where freight arrives by ship, is unloaded and warehoused, and then loaded onto trucks for delivery, or vice versa. Other modes may include aircraft and trains. Freight terminals may be ports, truck terminals located near airports, or train stations. Freight stations are train stations where freight is loaded and unloaded. They are placed both at the ends of the line and at break-of-gauge—where a railway of one gauge meets a railway of another gauge, preventing the train from continuing without converting gauges, making this a convenient point at which to move freight or passengers from one train to another, which is often faster than gauge conversion. (The major break-of-gauge still in use in the United States is in Antonito, Colorado. Most American rail systems are now standard gauge.)

Today most freight stations and many other freight terminals are transshipment terminals, meaning they handle freight that has not yet reached its destination but needs to be transferred from one vehicle to another (either from one train to another, or from a ship, plane, or truck to a train). Transshipment terminals are sometimes also called transport hubs, especially if they also handle passenger transport. When the shipment is international, transshipment usually occurs in a designated customs area, where customs checks can be performed and duties paid. For instance, cargo may arrive by freighter at a Pacific Coast port in the United States, having originated in Japan. It is inspected by the customs authority, the appropriate fees are paid, security checks are performed in order to comply with homeland security and immigration regulations,

and the freight is then transferred to other modes of freight transport, which might include freight trains, cargo planes, long-haul trucks, short-haul delivery vehicles for delivery to the local region, or other ships bound for other ports. Some transshipment ports only count ship-to-ship freight transfers as transshipment.

All ports include a seaport terminal where maritime cargo is processed. Modern cargo transport is based principally on containerization, which uses reusable containers (called intermodal containers, shipping containers, freight containers, or just “boxes” in various literature) of standardized sizes to hold freight in transit. Steel straps, wooden braces, synthetic webbing, or polyester lashes are used to keep freight in place inside a container, and air bags are inflated to occupy any empty space to prevent shifting during transport. These containers stack and lock together and, when properly packed, allow for maximum efficiency in freight movement. The containers can be transported by any mode: though they are long (typically 20, 40, 45, and 53 feet in length), their height and width are within the constraints of train and truck transport (though “high cube” containers are too tall to travel certain routes). Freight terminals where containers can be transferred from one vehicle to another are called container terminals. Most major cities and ports have a container terminal.

If the containers are not unpacked on-site or in a warehouse and are transported away from the terminal, they are loaded onto the flat bed of a truck, into a cargo aircraft, or onto a flatcar or well car of a train. Well cars are special train cars developed for container transport and can be double-stacked. Containerization is a transport solution that has solved numerous problems, simplifying the transfer of freight from one mode of transport to another by making the dimensions of freight consistent and predictable, as well as maximizing packing efficiency and accelerating the process of freight transfer on railroads at a break-of-gauge.

At any freight terminal, unloaded freight is either stored (warehoused) or cross-docked. Warehouses are an important part of ports and other freight terminals, and some are partially or fully automated, using automated conveyors, cranes, and storage and retrieval systems that respond to computer commands. Typically, goods are not stored in warehouses for long periods of time, unless they are



This seaport terminal at Port Elizabeth, New Jersey, seen here in 2010, can store thousands of standardized shipping containers at one time before they are sorted and transported to their next destinations. Containerization, an innovation that made the dimensions of freight consistent and predictable, has helped simplify the transfer of freight from one mode of transport to another.

waiting to be cleared by customs or some other regulatory body. Cross-docking has been increasingly popular, beginning in the 1930s in the trucking industry. Cross-docking is the distribution of freight from its incoming transport to outgoing transport (long-haul or otherwise) with minimal time spent in storage—often no time at all. Cross-docking facilities primarily store goods only long enough to sort them. Incoming freight may be headed to multiple destinations, and outgoing vehicles may be accepting freight from multiple origins. The storage phase of cross-docking lasts just long enough for this sorting operation to be performed, and sometimes for a vehicle to become available.

Cross-docking is key to the hub-and-spoke system, which treats a freight terminal as the hub of a metaphorical wheel, from which spokes radiate in the form of traffic from the center to destination nodes (and vice versa). Sea transport, of course, originally made this model necessary. Not every city had access to the sea and, at a minimum, freight would need to be transported from seaports (hubs)

across inland waterways (spokes), though overland routes also became common. As the railroads spread, overland transport became a more significant part of the infrastructure.

Train freight stations often include classification yards, where train cars are led down a drill track through a series of switches that divert them onto classification tracks. Classification yards sort cars according to their contents and destination. For example, trains from multiple destinations might arrive at a terminal carrying goods bound for various other destinations. Their cars are classified accordingly, such that trains can depart for their final destinations. The largest classification yards are called hump yards, with a drill track on a hill, where an engine pushes the car being classified to the top of the hill and lets it coast off the crest along its destination track. Hump yards are major operations, classifying thousands of cars a day to keep the country's rail traffic moving swiftly and smoothly.

Similarly, many cargo ships are feeder ships, transporting containers bound for various destinations

to container terminals, where they are sorted and loaded onto larger container ships bound for specific destinations. The hub-and-spoke concept at play in the function of freight terminals is familiar to most people, as it is similar to the concept used in air travel.

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See Also: Container Terminals; Freight Handling; Railroads, Freight; Trucking Industry; World Container Ports.

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Freight Transport, Intermodal and Multimodal

Used since the establishment of the first trade routes between human settlements, the association of two or more modes of transport in a transport chain to convey freight is an established and regular practice. However, it was only in the second half of the 20th century that it gained wide visibility and recognition. The introduction of containers in the 1960s dramatically reduced the handling times (from weeks to days) and costs (by 5 to 10-fold) of the transshipment operations between modes of transport.

The globalization phenomenon in the 1970s demanded increasingly efficient transport chains to link the factories often located in different countries. The 1990s were characterized by a growing environmental awareness worldwide. Gradually, governments started to favor green transport solutions that could make use of sustainable modes of transport (such as, rail, sea, and fluvial transport)

over others (notably, road and air transport). Finally, the 2000s were characterized by strong economic turmoil and severe recession. In times of economic austerity, transport agents look for increased value for their money, which may be obtained by combining several modes of transport.

The rationale for the utilization of transport chains depends on the combination of several factors, including but not limited to (1) demand factors, such as, transit times, prices, or reliability levels; (2) special transport requirements for goods, such as those contingent on fragility, dangerousness, perishability, or intrinsic value; (3) the natural geographical features of the route (such as rivers, mountains, or seas) or human-made features (such as, urban regions or location of ports or airports); and (4) a legal framework that may hinder or prevent the utilization of the mode in question. As an example, Switzerland has strict legislation concerning the amount of road traffic on designated routes.

Over the years, we have witnessed a progressive specialization of each mode of transport according to its operational characteristics. Air and deep sea transport are typically used in long-distance services, often on intercontinental routes, whereas road, rail, fluvial, and coastal sea transport are used in short-to-medium-distance services, commonly on continental routes. In an intermodal transport service the actual mix of transport services depends on the abovementioned four factors, using each one at its best scale and level of operations.

The United Nation distinguishes three concepts of freight transport chains:

- *Multimodal transport*. The carriage of goods by at least two different modes of transport.
- *Intermodal transport*. The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport in an integrated and door-to-door transport chain, without handling the goods themselves when changing modes.
- *Combined transport*. An intermodal transport where the major part of the journey is by rail, inland waterways, or sea, and where any initial and/or final legs carried out by road are as short as possible.

These three concepts are in real terms only two, because combined transport is a subset of intermodal transport with a strong sustainable perspective. The key difference between intermodal and multimodal transport lies in the notion of integration. Integration refers to the existence of an active role of coordination and management of the individual transport services. This role is designated as freight forwarding.

Freight forwarding aims to exploit potential synergies and eliminate eventual frictions among transport agents. Thus, the overall performance of an intermodal transport service is higher than the sum of each individual transport service's performance. By contrast, in a multimodal transport service no integration is required, thus the overall performance is a simple summation of the performances of the individual transport services, and it is necessarily lower than that of an intermodal transport service.

The achievement of stable and efficient intermodal transport services requires an adequate integration between the individual transport services. A "transport service's profile" refers to the set of operational and technological properties of the mode of transport (such as, speed, capacity, tariffs, schedules, etc.). The relative importance of each property in the integration depends on the customer's "demand requirements" (for example, the speed property may be irrelevant in the case of nonperishable products). During transshipment operations two modes of transport interact. If their profiles are not fit (that is, the properties are not compatible, as for example, different capacities or different time schedules), losses of efficiency will occur. These losses or "types of friction" exhibit different characteristics and may occur at different moments:

- *Type 1.* Friction that provokes losses of efficiency during the production of the transport service (for example, a delay in one transport service may prevent cargo being loaded on the following one).
- *Type 2.* Friction that prevents the detection and subsequent recovery of a problem (for example, the impossibility of a fast transfer connection for delayed passengers) during the production of the transport service.
- *Type 3.* Friction that prevents the customers from being compensated for the

problems that occur during the transport service. Typically, this happens after the production of the transport service (for example, nonagreement between stakeholders on the level of customer compensation).

"Dimensions of integration" refers to the nature of the interactions that occur during the production of an intermodal or comodal transport service. Along each dimension, friction may occur and lead to losses in the efficiency of the transport service. There are five dimensions of integration:

1. Physical integration refers to the level of interoperability between modes of transport and determines the ease of transferring the goods. (For example, the transshipment of containers between deep sea ships and trains is straightforward but not feasible with aircraft, as it is necessary to manually transfer the goods.)
2. Logical integration refers to the level of interoperability between the transport agents' IT systems and determines the ease of exchanging communication. (For example, noninteroperable IT systems preclude the early detection of delays or erroneous routing of the goods.)
3. Contractual integration refers to the nature of the transport contracts that define the sharing of responsibilities among transport agents in case of delays or damage to goods. (For example, the international transport conventions define different limits of liability for each mode of transport. As a consequence, therefore, the same goods may yield different levels of compensation depending on the location of the damage.)
4. Financial integration refers to the scheme of payments agreed between the transport operators. (For example, delays of payment and fluctuation of currency may result in lower payments than initially agreed.)
5. Relational integration refers to the transport agents' willingness to participate in intermodal transport services. The optimum of an intermodal transport solution may result in a suboptimal solution for

one or more single modal transport agent, which may not be acceptable. Also, participation requires sharing sensitive information with other transport agents who are often direct competitors in the market.

Intermodal transport has received a great deal of attention in the last decades as a potential solution to curb the unsustainable growth of road transport in continental distance services. Notwithstanding, intermodal transport exhibits major difficulties in competing in the market and continues to lag behind the other transport solutions, notably road transport. European and U.S. industry data on intermodal transport reported the market share between 5 percent and 10 percent for continental-level services. These figures contrast with intercontinental services in which intermodal transport (deep sea–road, deep sea–railroad, or air–road) is the only option to convey freight to destinations that are located outside the vicinity of ports or airports.

The reasons for such chronic underperformance are well known and lie in both internal sources of friction and external barriers. The “internal sources” refer to problems arising from the combination of different modes of transport with misfit profiles. As explained above, misfit profiles generate friction along one or more dimensions of integration. The “external barriers” refer to factors of context that are not controlled by the transport agents but that influence the way they organize themselves in transport chains. Multiple barriers have been identified and still persist with more or less intensity.

Functional misalignment of the transport network happens when many existent transport infrastructures have been planned and constructed at different periods of time, with different perspectives and requirements, not always compatible (for example, the European Commission reports that a high-speed rail service through France, Belgium, Germany, and the Netherlands has to adapt to seven different signaling systems).

Fragmentation of the transport network happens frequently when planning and spatial development impose constraints on the construction of transport terminals or infrastructures, resulting in suboptimal transportation systems, which are often not connected. Another problem occurs

when legal frameworks are modal specific and do not foresee multimodal arrangements, which leads to difficulties in case of conflict. Institutional separation by mode of transport occurs when public concessions for operating transport networks are modal based, which creates barriers to the construction and operation of multimodal transport networks. The actual mix of internal sources and external barriers will influence the risk of failure and the level of instability of the intermodal transport service.

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See Also: Air Cargo Carriers; Containerization/ Container Shipping; Inland Waterways, Freight Traffic and; Intermodal Freight Transport, Technology and; Railroad Industry, Economics of.

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Freight Transport, Security Issues

Transport planners and managers have wrestled with transport safety and security issues for years, but the terrorist attacks on the United States on September 11, 2001, catapulted the issue of physical security of goods to the forefront and elicited a response that has transformed the way goods are moved across America and the rest of the world in unprecedented ways.

Besides circumventing terrorist attacks, transported goods also need to be secured against threats to health, for example, accidents involving hazardous materials that disperse them over densely populated areas. Security concerns not only affect transporting goods by air, land, and sea but also the terminals where they are stored.

Terminals as Targets

Since railway stations and airports are some of the most densely populated transportation centers, managers have long been concerned about the safety of goods stored in their terminals. Traditionally, freight industry concerns have centered on worker safety and theft, because freight terminals are dangerous places to work. Every day in freight yards across the country, large machines and sweating workers load heavy goods onto vehicles, running the risk of numerous accidents. Worker education and improved methods of operation have made conditions safer over the years, but freight terminals are still dangerous places to work.

Thefts have been a constant and severe problem confronting freight terminals and, over time, companies have restricted access to them and used security staff (or contractors) to help control thefts. As globalization produced global supply chains, freight transport security emphasis is transforming into a more comprehensive and multilayered approach, with a particular focus on cargo integrity and the use of computer information systems to manage the supply chain. Establishing procedures to preserve the cargo, such as inspections, and to secure facilities, personnel, and data are also important measures.

Air Freight Security

Statistics from the Transportation Security Administration (TSA), an agency of the Department of Homeland Security established in 2001 to safeguard U.S. transportation systems and ensure safe air travel, illustrate part of the magnitude of monitoring air freight security. There are 19,576 general aviation airports, heliports, and landing strips across the United States and 459 commercial airports. The aftermath of September 11, 2001, created a new set of security issues and amplified the scale and scope of regulations and monitoring of cargo companies.

In 2010, the TSA introduced new regulations that mandate the screening of all domestic and

international air cargo in the United States before it is loaded. The Certified Cargo Screening Program requires airlines, freight forwarders, and shippers to pay for security measures as part of its program of establishing a secure air freight transport chain. This additional security mandate adds another problem to the air cargo industry, which is already coping with higher energy costs and weak demand. Several freight forwarders use maritime shipping facilities instead of air cargo for long-distance shipping, an unusual combination of shipping by both air and sea.

Maritime Transportation

There are 25,000 miles of commercial waterways in the United States, 361 ports, and 9 million containers passing through 51,000 ports of call. Maritime transport accounts for at least 80 percent of global trade and includes significant amounts of dangerous commodities—weapons, narcotics, ammunition, and other hazardous materials. The monitoring and security of maritime containers is complicated by the difficulty of detecting problematic containers, the global nature of the shipping industry, and the presence of terrorists and pirates.

The shipping container, the facilitator of globalization, makes it difficult to identify illicit or dangerous cargoes. Without scanners that can inspect the entire contents, each container must be checked manually, which is time consuming and an enormous task because of the large volumes of shipping. The growing international practice of hubbing—accumulating export and import cargoes at selected hubs from which to forward to their destinations—exacerbates the problem because hubbing requires multiple containers to be handled with minimum delays and inconvenience. Hubbing also increases the opportunity for sabotage.

In 2002, with the backing of the Department of Homeland Security, the United States enacted the Maritime Transportation and Security Act, and the International Maritime Organization adopted the basic elements of this legislation. The important provisions of this act include the requirement of installing an automated identity system for all vessels between 300 and 50,000 dead weight tonnage, ordering vessels to display a permanently marked and visible identity number, and requiring ships to have current records of flag, port of registry, and addresses of the registered owners.



A U.S. Customs and Border Protection officer, situated on top of a shipping container on board a vessel, opens a container panel for search and inspection at the Port of New York and New Jersey in Newark, New Jersey, November 6, 2012.

Another stipulation of the Maritime Transportation and Security Act states that each port must conduct a security assessment of its assets and facilities and estimate the effects of damages from a possible terrorist attack. The port must identify and evaluate the risks to and weaknesses in its physical security, communications system, utilities, and other resources. Another stipulation of the Maritime Transportation and Security Act is that all cargo destined for the United States must clear customs before the ship leaves port. There is also a move to establish biometric identification and an international database of sailors. The act is being implemented in ports around the world, and an uncertified port will find it difficult to trade with the United States, making security an important part of a port's competitiveness.

In 2008, Department of Homeland Security legislation required all containers shipped to the United States from foreign ports to be screened. Foreign ports must use gamma and X-ray scanners to examine all U.S.-bound containers, no matter what the security threat, causing more financial and operational obstacles for foreign countries wanting to trade with the United States.

The Department of Homeland Security's Container Security Initiative (CSI) allows U.S. Customs

and Border Protection (CBP), working with participating governments' customs services, to examine high-risk maritime containerized cargo at foreign seaports before it is loaded onto vessels that are bound for the United States. In 2012, more than 58 foreign ports participated in the Container Security Initiative, accounting for 85 percent of container traffic bound for the United States.

Freight Rail Security

The Federal Railroad Safety Act of 1970 defined railroad safety in the decades before 9/11. By the 1980s, the rail freight industry had been largely deregulated, and it prospered without too many safety issues. After 9/11, the TSA took over railroad security, affecting the ability of the railroads to control their own operations while ensuring security against terrorist attacks.

In a 2009 study titled "The Highlights of Freight Rail Security Actions in the United States Since the September 11, 2001, Terrorist Attack," which it conducted for the TSA, the U.S. Government Accountability Office (GAO) explored the probable effects of a terrorist attack on the U.S. freight rail system, which operates over 120,000 miles of major railroads. The U.S. rail system is an attractive terrorist target because it is publicly accessible, features long stretches of open and unattended track, and an attack could produce a catastrophic loss of life because the railroads cross densely populated urban areas. According to the Department of Transportation (DOT), freight rail is the major carrier of highly hazardous materials in the United States, typically hauling from 1.7 to 1.8 million carloads of hazardous materials a year.

The study examined the security status of the freight rail system, the actions that the railroads had taken to secure the system since 2001, and TSA's efforts to monitor and assess the effectiveness of any security precautions. The GAO recommended that the TSA focus on other areas of concern besides railroads transporting hazardous materials, including risks to critical infrastructure and cybersecurity. Pointing out that the freight rail industry has taken action to secure shipments and key infrastructure, the study recommended that the TSA create a mechanism to track security improvements on the railroads and assess their effectiveness. The TSA will strive to develop baseline security standards for all rail systems, assess operator security

status versus existing standards, develop a plan to close gaps in security standards, and enhance existing security standards.

Truck Security

Before 9/11, security concerns in the trucking industry tended to focus on variations of crime, cargo theft, and trucking or driver safety. With a few exceptions, like the Oklahoma City bombing on April 19, 1995, trucks have not been a typical target or weapon for terrorism. After the world-changing September 11, 2001, terrorist attacks, law enforcement personnel, national security analysts, and the U.S. Department of Homeland Security acknowledged that the trucking industry does indeed offer some important attractions to terrorism. These attractions include access, sizable volume, relatively cheap and viable energy, a vast operational environment, indispensability, and commonality.

More than 80 percent of U.S. communities depend solely on trucks for the products and goods they receive, including food, books, clothing, electronics, automobiles, and medical supplies. These trucks travel 3.9 million miles of public roads, and keeping trucks and their cargo safe is one of the TSA's security responsibilities, although the individual states and their authorities play an essential role in ensuring general security as one of their basic operating responsibilities.

In 2009, the American Trucking Association (ATA) published the *ATA Certified Cargo Security Professional Resource Guidebook*, a 186-page manual that helps readers evaluate and manage risk and trucking security from pickup to delivery. Developed by the ATA's Security Council, the book provides a security blueprint for facilities, personnel, information, and computer security. It covers federal security regulations for hazardous materials transportation, cross-border security, and intermodal security.

The International Road Transport Union focuses entirely on security measures against terrorism. In its *Transport Security Guidelines*, the group states that the goodwill and active participation of local and state authorities are essential to the success of any security program. Keeping trucks and hauling vehicles safe is a balancing act. If security procedures are too stringent, the business of transporting goods could be stalled, drastically disrupting the U.S. economy and giving terrorists a victory, while lax security measures will give them an opportunity

for an attack. Transportation companies must balance a sensible and sensitive middle line and never forget that zero risk does not exist and total security can never be guaranteed.

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See Also: Airport Security; Containerization/ Container Shipping; Freight Terminals; Harbor and Port Security; Hazardous Materials Transport; Security, Transportation; Terrorism, Transportation Systems as Targets of; World Container Ports.

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Freight Transport Models

Globalization, economic development, and new information technologies have been spurring consumption and trade among nations. Available forecasts predict significant growth in freight demand

in many regions worldwide in the coming decades. Such growth is likely to generate significant impact on the current transportation systems (in terms of congestion and accidents) and the environment (in terms of increase of emissions of greenhouse gases and depletion of natural resources). There is therefore the need to increase the efficiency and promote the sustainability of freight transport systems and to mitigate the conflicts with other users (including private cars, bikers, and even pedestrians).

The identification of adequate solutions often requires field experimentation of new concepts and multiple alternatives. However, field experimentations in transportation require a significant amount of resources (human, equipment, capital, etc.) without any real assurance of return, besides inevitably introducing disturbance or disruption into the transport systems. It is at this moment that models can be quite useful. Models are cost-efficient alternatives to field tests and provide fully controllable environments for testing alternative hypotheses and scenarios.

A model is a simplified representation of a real-world situation (although it can also be used to study imaginary conditions). It contains the minimum amount of detail (in terms of variables, features, or detail) to adequately permit the study of the problem. The simplification is required for reducing the complexity of the real world to manageable levels for an efficient development of the model. However, simplification also denotes that particular aspects of the real world are not considered in the analyses. Therefore, the outcomes of a model are by definition inaccurate or, in other words, have a degree of uncertainty, which tends to increase with the level of simplification. Even so, models have proven very useful to forecast demand for transport services and to estimate the impact of changes in the transportation system.

Passenger transport models are more established and developed than freight transport models. Understandably, the primary political and societal interest was on improving the transport of people, which eventually drove academic endeavor. Indeed, the initial freight transport models were inspired by the passenger models. Yet people and freight exhibit significantly different transport patterns and behaviors, and before long, the need for tailor-made models was recognized.

Freight transport models have been applied to a wide variety of geographical areas, ranging from the city district level up to the continental level. The size of the geographical area is relevant in the modeling process because it influences the zoning. Zoning is the process of dividing the geographical area of study into a set of smaller regions—zones. The modeling parameters are considered homogenous within each zone. They are normally equal to the average value of some of the individual elements of each zone. Zoning thus reduces the inherent complexity of the real world to a manageable level. As it introduces errors in the analysis, the number and shape of the zones should be carefully considered.

The European Union–cofunded research project SPOTLIGHTS-TN identified a total of 65 freight transport models and 29 joint passenger and freight transport models in a universe of 222 transport models. Compared with the passenger side, freight transport modeling lags behind considerably. Even so, substantial progress has been achieved and there is now a rich assortment of models. Typically, classification is done according to their primary purpose, as discussed below.

Models for Production/Attraction of Freight

The purpose of these models is to estimate the amount of freight produced and consumed in every zone. Several models have been developed. Trend and time series models use historical data to build correlation function and to extrapolate future values. Multiple methods have been proposed to build the correlation functions. As an example, the growth factor method uses a multiplier to convert past data into future values. Multipliers can be obtained through interviews with experts, economic correlations, or even past trends. Other more complex approaches include, for example, autoregressive correlations.

A similar method—zonal trip rate models—relies on collected data of traffic volumes leaving or entering the zones. The detail of the data is case-specific but may include, besides volumes and quantities, trips per mode of transport, the nature of the goods, or the origin and destination of locations.

Economic models rely on regional economic activity to estimate the production and consumption of goods in each zone. These models are, in many developed regions, developed by the national statistics offices.

The ASTRA—assessment of transport strategies—model uses a system dynamics approach to link the growth of gross domestic product (GDP) at the national level to the freight transport demand at the regional level.

Models for Distribution

The purpose of these models is to determine the flow of goods between each pair of zones. The results are normally presented in a table format (see Table 1), designated as an origin–destination matrix (OD matrix). Each cell contains the estimated freight conveyed from the origin zone to the destination zone.

Gravity models are the most commonly used methods to determine the flows. These methods are inspired by the well-known gravitational law that states that the attraction between any two bodies is the function of the production of their masses divided by the square of the distance between them. Gravity models state that the flow X_{ij} is the function of the product between the production at the origin O_i and the attraction of destination D_j divided by the impedance to moving the freight between O_i and D_j . Production and attraction are normally measured using the above models for production and attraction of freight. Impedance is normally measured by a transport cost function. Transport cost functions may cover a wide range of resistance to transport, specifically, distance, tolls, taxes, transshipment operations, etc. These methods have limited data requirements and allow the assessment of transport policies through the transport cost functions. Conversely, the scope for including explanatory

variables is rather limited and the number of calibration parameters is limited. The Dutch TEM-II model uses a gravity model.

Economic models are another method to determine the distribution of the flows. These methods, described in the previous section, use the economic data to determine the supply and demand of freight of each zone (output of the models for production and attraction of freight) and respective distribution between zones. These methods have the advantage of being linked to regional economy and land development. They can provide information on the transport and land use interactions and, in specific circumstances, be used to assess policy effects. However, they require a substantial amount of data with a level of detail that is often difficult to obtain. Furthermore, these methods utilize tons while many available statistics report the freight in value. In such cases, a transformation of value into tons is required. Examples include the Strategic Transport Research for European Member States (STREAMS) project and the Scenarios for European Transport Models (SCENES) project.

Models for Modal Split

The purpose of these models is to allocate freight flows (between each pair of zones) to the available transport services. The transport services can be either single modal (for example, road, train, or sea) or intermodal (for example, road and train, or road and sea). It is important to note that the available transport services depend on the available transport infrastructure and transport operators and, thus, they may change between pairs of zones. A wide set of models are possible. Economic models are normally grounded in the theory of the firm. They build the transport agent cost function, in which the available transport services are considered as one of the inputs. Demand functions, based on the costs function, can then be derived. Tae Oum presents a freight transport model using this approach.

Disaggregated modal split models represent the shipping firm's decision-making process. They are grounded in the assumption that shipping firms are rational and will opt for the transport solutions that maximize their benefits or utility. Utility functions are then built for typologies of firms, normally using the multinomial logit or the nested logit methods. These methods require a substantial amount of data, which may not be

Table 1 Origin–destination matrix

		Destination Zones			
		D_1	D_2	...	D_n
Origin Zone	O_1	X_{11}	X_{12}	...	X_{1n}
	O_2	X_{21}	X_{22}	...	X_{2n}
	...	...	...	...	...
	O_m	X_{m1}	X_{m2}	...	X_{mn}

Source: Vasco Reis

readily available. Typical sources include surveys of companies and transport companies, and available statistics on freight flows. Gerard de Jong and colleagues present a freight transport model using this approach.

Aggregated modal split models estimate the average market share of the transport services. These models, rather than modeling the decision making of individual firms, rely on available statistics (modal share for a number of zones) to infer the utility functions, normally in the form of the binomial or multinomial logit models, of each transport service. The validity interval of the utilities functions is therefore limited to source zone flows. These models have limited data requirements. However, since they work with average values, they provide little information on the causality effects underlying the results. Gust Blauwens and Eddy Van de Voorde present a freight transport model using this approach.

Models for Trip Assignment

The purpose of these models is to allocate vehicle trips to the transport services. This requires a diversified amount of information, including vehicle capacity, schedules, or occupancy levels. In the case of road transport, it also involves assigning trips to paths and links—routes. Since freight vehicles share the infrastructure network with passenger vehicles, often both assignments are simultaneous—traffic assignment. These models assume that the agents behave rationally and choose the paths with lower costs. As such, the equilibrium of a network is obtained when no vehicle can change a route without increasing its costs. Limited capacity of the road network and therefore congestion problems can be considered with the introduction of penalties (such as an increase in transit time or an increase in fuel consumption).

An important aspect is related to driver access to information about the network congestion levels (present and future). Some models consider that drivers have full access to information, while other models consider that drivers only have partial access. In the latter case, drivers can make decisions based on outdated information and may end up choosing links that are congested. These situations lead to suboptimal situations being closer to reality, in which drivers have no knowledge of the network and respective traffic conditions. The STAN

and NODUS are two well-known models for trip assignment.

Other Models

Many models embrace several or all of these functions. The four-step model, for example, is arguably the best known modeling concept for both passenger and freight transport models. The modeling concept was initially developed for passenger transport but was soon adapted for freight transport. The name results from the model being structured in four sequential steps, which correspond to the above-mentioned models, that is, production and attraction, distribution, modal split, and assignment. The popularity of this concept is due to the simple and easy-to-understand organization.

Other models embracing several functions are the national freight transport models. These models are commissioned by the national governments to support transport-oriented policy development. These include the Dutch Strategic Model for Integrated Logistic Evaluation model (SMILE), the Swedish SAMGODS model, or the Norwegian Network model for freight transport within Norway and between Norway and other countries (NEMO). The European Commission financed the development of the European Transport Network model Tools for Transport Forecasting and Scenario Testing (TRANS-TOOLS).

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See Also: Equilibrium Modeling; Full-Feedback Modeling; Networks Modeling; Transportation Modeling and Planning Software; Urban Transportation Modeling System.

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Full-Feedback Modeling

Transportation planning and the need for travel demand models has been recognized by urban planners and researchers for over a century. Transportation modeling has been used for infrastructure planning and policy analysis for decades. The planning process requires estimates of current use of a surface transportation system, including highway, transit, nonmotorized, and freight modes. Travel forecasting models are used to study proposed investments in the transportation system and determine which of these investments will best serve the public's needs for future travel and economic development. The models are also used to determine air quality impacts of proposed transportation projects, to evaluate the impacts of alternative land use, and to forecast energy consumption.

With passage of the 1990 federal Clean Air Act Amendments (CAAA), the 1991 federal Intermodal Surface Transportation Efficiency Act (ISTEA), and the National Environmental Policy Act (NEPA), a resurgence of interest in improving travel demand model behaviors and forecasting techniques has been evidenced throughout the country. The federal government, state transportation agencies (STAs), and metropolitan planning organizations (MPOs) have historically shared responsibilities for developing transportation models and making urban travel forecasts.

Initially, federal agencies took the lead in developing travel forecasting methods; over time, these responsibilities have shifted to the states, MPOs, and the private sector. The federal government has not become invisible with respect to metropolitan travel forecasting, however. A travel forecasting process with which to estimate travel impacts and facility needs is necessary to meet the requirements of federal laws, such as those mentioned above. In fact, every urban area in the United States with a population of 50,000 or more must undergo a metropolitan transportation planning process as a precondition for federal funding of transportation projects.

Travel Demand Models

A transportation model, also known as a travel demand forecasting model, is a computer-based mathematical model that simulates supply and demand for travel in a given (usually urban) area. Models are used in a sequence of steps to answer a

series of questions about future travel patterns. The basic questions asked in each transportation modeling step are as follows:

1. What will our community look like in the future?
 - a. How many people will there be?
(population forecasts)
 - b. What will they be doing?
(economic forecasts)
 - c. Where will activities take place?
(land use)
2. What will be the travel patterns in the future?
 - a. How many trips will be made?
(trip generation)
 - b. Where will the trips be?
(trip distribution)
 - c. What modes will be used?
(mode split)
 - d. What routes will be used?
(traffic assignment)
 - e. What will be the effects of this travel?
(impact analysis)

These models are highly complex and require (as inputs) extensive current information on roadway and transit system characteristics and operations, as well as current and forecast demographic information. Creating and operating the models requires a high degree of technical training and expertise. Once a model is developed that replicates existing travel conditions, future conditions and alternatives can be evaluated in terms of their impact on the transportation system.

The most common paradigm for travel demand models in the United States is known as the "four-step model" (FSM) due to its four main steps: trip generation, trip distribution, mode choice, and trip assignment. This model is known as a trip-based model (TBM). The travel supply is generally represented by a highway network and a transit network. The highway network represents all major roads in the region and the transit network represents all public transportation service in the region, such as bus, rail, and commuter rail.

The demand for travel is developed using a series of mathematical models. The first three steps of a trip-based FSM travel model are used to estimate

the demand for travel. In the fourth step, trip assignment, the travel demand is equilibrated with the travel supply, as trips are loaded onto one or more transportation networks. The geographic unit of analysis in a four-step model is the transportation analysis zone (TAZ). Usually an urban area is divided into hundreds or thousands of transportation analysis zones.

In the past decade, planners and policy makers have begun asking more complex questions, such as: How might rising fuel prices affect the choice of locations for living, working, shopping, and leisure activities, or travel behavior? What impact do road use charges have on vehicle types, occupancy, peak-hour travel, or level of congestion? What are the impacts of alternative development scenarios, such as smart growth strategies, on traffic volumes? How do rising freight volumes impact traffic flows at different time-of-day periods? These and other questions asked by policy makers are difficult to answer with traditional modeling approaches. New methods of transportation modeling have been developed and are now increasing in use.

An alternate approach to the trip-based model is the activity-based model (ABM). Although academics and researchers have been studying ABMs for years, it is only recently that some urban planners have begun to develop or adopt activity-based models. Whereas trip-based models use the trip as the basic unit of analysis, ABMs assume that travel is a derived, or produced, demand (from the need to participate in various activities throughout the day) and use a combination of trips and tours (collections of linked trips beginning at home) as the unit of analysis. Tour-based models overcome much of the knowledge loss associated with trip-based models because these trips in the model “have some knowledge” of their context. Both TBMs and ABMs have been successfully used over the years to address policy and investment options at urban and statewide levels.

More Recent Models

Other models that have been used more recently are land use models, freight and commercial movement models, and statewide models. Land use models are used because they test land use policies and they can be integrated with travel models to simulate the interaction between them. New transportation infrastructure affects land use patterns;

the transportation/land use feedback cycle explains how transportation influences land use and how, in turn, land use creates transportation demand. Integrating a transportation model with a land use model implements the entire feedback cycle, which helps account for induced travel demand.

Commercial movement models have been implemented to account for their growing share of traffic congestion. Freight and commercial vehicles react quite differently to many transportation policies and network conditions. These trips may be more sensitive to changes in travel time, requiring models that more appropriately account for these differences. Statewide models have been implemented to analyze policies at the regional level. For example, development of a new roadway may assist in local traffic patterns but cause travel difficulties on longer routes. Regional models take into account the scope of a larger picture beyond the often artificial boundaries of a city.

The traditional four-step, trip and activity-based model provides a mechanism to determine equilibrium flows. First, in trip generation, measures of trip frequency are developed, providing the propensity to travel. Trips are represented by beginning and end points, or productions and attractions, which are estimated separately. Next, in trip distribution, trip productions are distributed to match the trip attraction distribution and to reflect any underlying travel impedance (such as time or cost), yielding trip tables of person-trip demands. Next, in mode choice, trip tables are essentially factored to reflect relative proportions of trips by alternative modes. Finally, in route choice, modal trip tables are assigned to mode-specific networks.

Time of day is typically introduced after trip distribution or mode choice where the production-attraction tables are factored to reflect observed distributions of trips in defined periods (such as the A.M. or P.M. peaks). Total demand, as specified through generation, distribution, mode choice, and time-of-day models, is fixed, with only the route decision to be determined. Most applications of the FSM feedback equilibrate link travel times to the mode choice or trip distribution models for a second pass through the last three steps. Integrated land use and transportation models are absent in most U.S. applications, and although they have gained some popularity, most metropolitan planning organizations still use the four-step model.

The FSM falls short, as the demands on forecasting models have grown significantly in recent years. Existing models are inadequate to address many new policies, such as estimating motor vehicle emissions and evaluating alternative land use policies. The four-step model is inherently weak in that it does not address individual travel behaviors. It cannot be expected to represent the conditions of an individual traveler choosing how, when, and where to travel. As a consequence, time chosen for travel, travel behavior, time-specific traffic volumes and speeds, freight and commercial vehicle movements, and nonmotorized travel cannot be accounted for accurately.

Improvements to the FSM have been made in recent years. In some cases models can be modified to accommodate additional factors or procedures, while in other cases major modifications are needed or new software is required. The following are some potential modifications of models that may help improve their usefulness: better data, that is, recent data that represent all components of the population to use to calibrate the models and to provide for checks of their accuracy; improved representation of bicycle and pedestrian travel; better vehicle occupancy models; better time-of-day procedures; more trip purpose data (market segments); better representation of access; incorporation of costs into trip distribution; add land use feedback; add inter-section delays.

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See Also: Benefit–Cost Analysis of Transportation; Equilibrium Modeling; Federal Transportation Policy; Highway Planning; Networks Modeling; Planning, Programming, and Budgeting Systems; Transportation Modeling and Planning Software; Transportation Plan Implementation Monitoring and Evaluation; Transportation Planning and Politics; Transportation Statistics and Databases; Urban Transportation Modeling System.

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Funicular Railways

Funicular railways combine the elevator operating principles of a cable pulling a car upward with the railroad technology of a car on a track with a haulage cable controlling its movements. For centuries, countries all over the world have used funicular elevators and railroads on inclines to transport people and goods up steep hillsides and in modern times to carry skiers up and down mountains. Although funicular railways still operate worldwide and new ones are still being built, the technology dates back to the 16th century. Modern funicular builders use technologically advanced materials, built on the foundation of the historic funicular concept. Funicular railways operating in the 21st century were created and are operated in as many different ways as the sizes and shapes of the passengers that ride them.

Innovative Funicular Railways

The city of Dana Point, California, operates the Strands Beach Funicular, which since 2009 has carried people between the beach and the top of the hill overlooking it. Closely resembling an inclined elevator, the Strands Beach Funicular is powered by an electric motor on the car itself and it runs on a

cog rail system. The car can carry up to eight passengers and it provides easier access to the beach for the public and disabled people. The Strands Beach Funicular travels about 2 to 3 miles per hour.

A funicular called the Normal Railroad, or Western Trolley, operated on the campus of Western Michigan University in Kalamazoo, Michigan, from 1908 until 1949. In the early 1900s, the main campus of Western Michigan University, then called the Western State Normal School, stood on Prospect Hill—now known as East Campus. Students and teachers had to climb up 150 steps to reach the building in both good and bad weather, so the school administration built a funicular railway along the northeast corner of the hill with two tracks, each with a car hauled by a cable. At its peak the railroad carried 2,280 passengers a day, but eventually rising maintenance costs combined with the popularity of the automobile destroyed the funicular and it closed in 1949.

In 2002, at Western Michigan University, four senior engineering majors decided to build an operational replica of one of the trolleys, a difficult task because a bench that a faculty member had saved was the only artifact left from the original funicular. Although sketches and photographs had survived, there were no blueprints of the original funicular. Overcoming all obstacles, the engineering students unveiled the replica trolley on April 8, 2003, and it occupies a prominent place on Western Michigan University's main campus. Western Michigan students, alumni, and local residents ride the funicular and testify to its authentic restoration.

The Fenelon Place Elevator began in the imagination of banker J. K. Graves, who lived on top of the Mississippi River bluffs in Dubuque, Iowa, and worked at the bottom. Every day he spent hours driving his horse and buggy back and forth to work. As a traveler Graves had seen incline railways in Europe, and he believed that a funicular railroad would ride the Dubuque bluffs well. He petitioned the City of Dubuque for the right to build a railroad and the city granted him the franchise on June 5, 1882. He hired local engineer John Bell to design and build a one-car cable patterned after the cable cars in the Alps.

The original Fenelon Place cable took its first trip on July 25, 1882, and after that Graves had his gardener send him down in the car in the morning, bring him up at noon, down after dinner and his

nap, and up again at the end of the workday. Before long, his neighbors joined him and grew to depend on the Fenelon Place Cable to commute to work, shopping, and church.

Eventually Graves gave the franchise for the track right-of-way to 10 of his neighbors who banded together and formed the Fenelon Place Elevator Company. The members of the Fenelon Place Elevator Company traveled to the 1893 World's Columbian Exposition in Chicago, Illinois, to look for material for their funicular, and they brought back a streetcar motor to run the elevator, the turnstile, and steel cable for the cars. They also installed three rails with a fourth bypass in the middle to allow for the operation of two counterbalanced cars.

In 1897, C. B. Trewin built a house next door to the elevator, and by 1912 he had become the sole stockholder of the Fenelon Place Elevator Company because the original 10 stockholders had died or moved away. His family has owned and operated the elevator since then. In 1977, the cable cars were completely rebuilt and, after 84 years, the owners replaced the original gear drive with a modern gearbox with a DC motor. The elevator anchors a shopping district called Cable Car Square.

Angels Flight, Los Angeles

Angels Flight, a funicular railway located in the Bunker Hill district of downtown Los Angeles, California, has two funicular cars: Sinai and Olivet. The funicular operated on two different sites with the same cars and station elements. The original Angels Flight operated from 1901 until 1969, when its site was cleared for redevelopment.

Colonel J. W. Eddy and other backers operating as the Los Angeles Incline Railway, financed Angels Flight, which became the railway's official name in 1912 when the Funding Company of California purchased the railway. The original Angels Flight had two cars connected to the same cable, and although it didn't have track brakes, it did have a separate safety cable in case the main cable broke. It operated safely for 68 years.

The first Angels Flight closed in 1969, after Los Angeles city planners decided that the Bunker Hill area needed complete redevelopment to replace the older, shabbier buildings with a modern mixed-use district of commercial buildings and modern apartment and condominium complexes. The Los Angeles Incline Railway put the components of Angels

Flight in storage until the railway could be restored and reopened.

The second Angels Flight opened a block south of the original site in 1996, with its tracks connecting Hill Street and California Plaza linking the city's Historic Core and Broadway Commercial District with the Bunker Hill California Plaza urban park on the hilltop and the Museum of Contemporary Art. On October 13, 2000, Angels Flight was added to the National Register of Historic Places, but then, on February 1, 2001, disaster struck. Angels Flight car Sinai reversed direction while approaching the upper station and accelerated downhill and struck car Olivet near the lower terminal, killing one person and injuring seven others.

The National Transportation Safety Board (NTSB) investigated and found that improper design and construction of the Angels Flight funicular drive and failure of regulatory agencies to enforce funicular safety standards had caused the accident. After repairs and repeated testing of its new drive and safety systems, the NTSB and the California Public Utilities Commission approved the safety certificate for the railroad to reopen on March 15, 2010. Just over a year later on June 10, 2011, the California Public Utilities Commission ordered Angels Flight to immediately cease operations because the steel wheels on the two cars were dangerously worn. Inspectors discovered that the 15-year-old wheels needed replacing, and Angels Flight reopened on July 5, 2011, after workers installed eight new custom-made steel wheels on the two cars.

Pittsburgh and Johnstown

The funiculars in Pittsburgh were built with public money for public use and operated by the local transit authority. Pittsburgh enjoyed an industrial boom in the 1860s and a demand for labor attracted German immigrants who needed housing. Since factories sprawled over the flat lands near the Monongahela River, people built houses on the steep hillsides above the river where no good roads or public transportation existed. The German immigrants remembered their *seilbahns*, or cable cars, at home and they suggested constructing inclines to carry people up and down Mount Washington and other hills.

Built in 1870, the Monongahela Incline is the oldest continuously operating funicular in the United



A view of the Duquesne Incline funicular showing the cables running between the rails on Mount Washington in Pittsburgh, Pennsylvania, in 2007. The 1877 Duquesne Incline nearly closed for good in 1962 but was saved by a community-based effort.

States and, along with the Duquesne Incline, survives from the original 17 funiculars built in Pittsburgh. The Port Authority of Allegheny County operates the Monongahela Incline, and transfers from the light rail and buses can be used on the funicular. Its lower terminal is located across the street from the Station Square shopping complex.

Opened in 1877, the Duquesne Incline scales Mt. Washington and is located near Pittsburgh's South Side neighborhood. In 1962, the Duquesne Incline closed, supposedly for good, because it had few patrons, needed major repairs, and its private owners were not interested in continuing it. Duquesne Heights residents conducted a fundraiser to save their funicular, formed a nonprofit organization to preserve it, and it reopened on July 1, 1963. It is one of Pittsburgh's most popular tourist attractions and local residents use it to commute to school and work.

Advertised as the world's steepest vehicular inclined plane, the Johnstown Inclined Plane carries automobiles and passengers between the city of Johnstown and the borough of Westmont on Yoder Hill. After the catastrophic flood of 1889, citizens of Johnstown searched for an escape route from future

floods and convenient transportation from Johnstown to the new communities above the valley. After its opening in 1891, the Cambria Iron Company and its successor, the Bethlehem Steel Company, operated the Johnstown Inclined Plane until 1935, when they sold it to the borough of Westmont. It underwent major renovations in 1962 and from 1983 to 1984, and in 1994 it was designated a Historic Mechanical Engineering Landmark. In 2011, the Johnstown Inclined Plane had a ridership of 81,236 passengers.

Future Planning

Traditional funiculars were enclosed vehicles running up and down a mountain, but funiculars in Cincinnati were different. They were just gated platforms fairly level to the horizon, with entrances and exits aligned with the existing street grid instead of the sidewalk. This pared-down design allowed horse-and-wagon teams to board the funicular from the street below, travel up the mountain, and enter the street above with little effort. As technology progressed, streetcars, trolleys, and buses did the same thing.

Cincinnati's funiculars and their design concept vanished with the dominance of rail transit systems, buses, and private automobiles, all of which could almost effortlessly scale mountains. Rail systems, including light rail, streetcars, and subways,

are technologically limited by how steeply they can climb, which restricts their operation to mostly flat locations, but when they are partnered with a Cincinnati-styled funicular, they can exponentially expand their range of operations. Municipalities considering installing light rail transit systems might well study Cincinnati-style funiculars.

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See Also: Aerial Tramways; Cable Cars; Streetcars/Trolleys; Transportation Planning; Tramways.

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Gasoline, Reformulated

Gasoline is currently the fuel that powers most vehicles traveling on streets and roads. Gasoline generates energy by changing a hydrocarbon (which is comprised solely of hydrogen and carbon) to water and carbon dioxide (CO_2). Because gasoline is a fossil fuel derivative, combustion leads to the emission of noxious pollutants into the ambient atmosphere. As the number of cars on the road (and vehicle miles driven) increases, the resulting pollution worsens. This is especially problematic in places with high vehicle density. To mitigate this problem, some cities or regions have been requiring the use of reformulated gasoline. Reformulated gasoline is designed to burn cleaner, reducing the amount of potentially dangerous emissions and smog-forming chemicals to the air.

Characteristics

Gasoline is a volatile substance. Volatility, the propensity of a chemical substance to evaporate under normal thermal and pressure conditions, is a function of vapor pressure. One typical way of evaluating how volatile a fuel can be is by its Reid vapor pressure (RVP), which describes the rapidity with which fuels evaporate. Larger (smaller) values indicate greater (lesser) volatility. Measured in pounds per square inch (psi), there is no single satisfactory value of RVP for gasoline, as a suitable value

depends on temperature (and by extension, season of the year). For example, a reduced volatility may be desirable under hot conditions, as it decreases the potential for vapor lock to occur. On the other hand, increased volatility under cold conditions makes it easier to start an automobile. In the United States, RVP standards must be met during summer by conventional gasoline.

Although gasoline is derived from crude oil, it contains numerous additives. These include such substances as toluene (to boost octane) and benzene (as an antiknock agent). Both gasoline's fundamental constituents, as well as the extra additives, contribute to the soup of unwanted chemicals emitted into the surrounding air.

Reformulated gasoline is gasoline that has been modified to lessen the toxic emissions released to the surrounding atmosphere. These discharges include nonmethane hydrocarbons (NMHCs), carbon monoxide (CO), and nitrogen oxides. The latter are nitrogen monoxide, also known as nitric oxide (NO) and nitrogen dioxide (NO_2); collectively, they are commonly referred to as NO_x . Carbon monoxide is one of the most noxious by-products of fossil fuel combustion, and the dangers of breathing concentrated amounts of this gas in enclosed areas are commonly known. Nitrogen oxides result from nitrogen and oxygen reactions occurring during the combustion of fossil fuels such as gasoline.

A cleaner burning fuel also needs to be usable by standard automobile engines. Reformulated gasoline is safe enough to use without affecting engine performance. Many major automobile manufacturers, including General Motors, Ford, Mitsubishi, and Nissan, support and endorse the use of the oxygenated fuels (fuels that have oxygen added to burn cleaner), noting the environmental benefits. Other manufacturers, while not issuing outright endorsements, note that oxygenated fuels may be used, though typically stating a disclaimer that ethanol (the oxygenating compound in some fuels) content be no more than 10 percent by volume. Additionally, there is no danger of engine or fuel system damage if users of reformulated gasoline switch to conventional gasoline in locations where the altered fuel is unavailable; the converse is true as well.

Policies to Reduce Risk From Emissions

Recognizing both environmental problems and air pollution risks to human health, the United States created the Clean Air Act in 1970 (it was signed into law by then president Richard M. Nixon). In 1990, the U.S. Environmental Protection Agency (EPA) amended the Clean Air Act to address the issue of low-level tropospheric pollution by strengthening existing provisions as well as instituting new concepts and directives. These were designed with the aim of reducing air pollution, especially that which related to traffic and the use of motor vehicles. One such new provision required the use of reformulated gasoline in nine regions that were particularly hard hit by smog and air pollution. Regions that were out of compliance with the ozone level set by the National Ambient Air Quality Standards (NAAQS) were obligated to sell reformulated gasoline by January 1, 1995, based on the initial phase of the Clean Air Act's amendments. The nine metropolitan regions deemed by the EPA to mandate the sale of reformulated gasoline in Phase 1 were identified based on levels of ozone. Those regions were Baltimore (Maryland), Chicago (Illinois), Hartford (Connecticut), Houston (Texas), Los Angeles (California), Milwaukee (Wisconsin), New York City, Philadelphia (Pennsylvania), and San Diego (California). Reformulated gasoline was also required for use in several (smaller) U.S. states—Connecticut, Delaware, Massachusetts, New Jersey, and Rhode Island—as well as the District of Columbia. This

program, however, was not limited to the mandatory regions. Additional metropolitan areas could join the program voluntarily.

One aim of the EPA's mandate to use reformulated gasoline was to reduce the amount of volatile organic compounds (VOCs) entering the ambient atmosphere. VOCs have low boiling points (as well as high vapor pressures); the boiling points of acetone and benzene (both VOCs), for example, are approximately 56 degrees C (133 degrees F) and 80 degrees C (176 degrees F), respectively. VOCs are largely anthropogenic (man-made) in origin. The components making up gasoline are responsible for its relatively high volatility (compared to some other fuels); these components include both normal compounds and those that have been subsequently added. These formulations can be modified to change the volatility. Reformulated gasoline, then, is gasoline that has been altered to lessen the amount of VOCs released to the atmosphere.

The original regulations called for oxygen to be added to fuels at a level of 2 percent (or greater) by weight. Other factors required for gasoline to qualify as reformulated included a limit on the amount of benzene permitted (less than or equal to 1 percent by volume); NO_x emissions that remained stable (or decreased); and an absence of heavy metals (types of toxic pollutants), although the latter requirement could be waived under certain circumstances. Target reductions of VOC emissions (assessed with respect to baseline emissions) also needed to be met. In 2006, the EPA's requirement that oxygenates be added to reformulated gasoline was called off. This permitted producers greater latitude in producing cleaner burning blends that would meet air quality standards.

The United States is not the only country employing vehicle fuel modifications in an effort to reduce the emission of pollutants and improve local and regional air quality. Several European countries have been involved with air quality monitoring and modeling in an effort to generate cleaner environments.

Risks and Consequences Related to Emissions

Health risks to humans can be mitigated by the reformulation of fuels. Various government agencies and institutions plan to enact or have enacted policies designed to decrease the potential damage to humans resulting from exposure to noxious gases emanating from vehicle exhaust. Although

there are up-front costs involved in switching to cleaner, reformulated gasoline, those costs may ultimately lead to greater overall savings, as healthier populations require fewer resources spent on treating health conditions attributed to toxic emissions.

Stratospheric ozone (the variety associated with the ozone hole and sometimes called “good” ozone) provides a protective layer that absorbs harmful ultraviolet (UV) radiation emanating from the sun. In the troposphere, however, ozone acts as a pollutant. High levels of ozone are associated with compromised human health, such as respiratory problems (including asthma and emphysema) and the risk of premature births or low birth-weight babies. Alerts may be issued on days of especially high ozone, suggesting that those with breathing problems, such as asthma, take extra care to avoid unnecessary exposure to ozone-laden air. The health risks associated with tropospheric ozone were an impetus for requiring reformulated gasoline to be sold where ozone levels exceed federal standards.

Smog is another consequence of the deleterious effects caused by traditional gasoline (and which reformulation aims to mitigate). First coined in 1905, the term *smog* is a verbal combination of the words *smoke* and *fog*. Smog originally referred to the thick pollution blanketing urban regions where substantial quantities of coal were burned for both heating homes and industrial activities. Today, though, smog describes a type of air pollution that develops primarily when solar radiation interacts with motor vehicle emissions (although some other emissions, such as those from industry, also contribute to the generation of smog). This is called “photochemical smog.” Photochemical smog is created when solar radiation reacts with VOCs and NO_x ; these are present largely because of the burning of gasoline by motor vehicles. This form of pollution is a particular problem in urban areas where the combination of sunlight and a large volume of motor vehicle traffic is coupled with atmospheric and topographic conditions that inhibit the dispersal of pollutants. Los Angeles (United States) and Mexico City (Mexico) are, for example, synonymous with smog, in part because of the frequent temperature inversions that act as a lid and trap pollutants in a near-surface layer and the cities’ locations in mountain basins that limit the advection (horizontal movement) of air. Reformulated gasoline is designed to reduce the emissions that lead to smog.



The price of E85 fuel (85 percent ethanol and 15 percent gasoline) is lowered during a promotion by the sugarcane ethanol industry in Birmingham, Alabama, April 2010. Ethanol can replace methyl tertiary butyl ether (MTBE) as an oxygen additive to gasoline.

The chemistry behind photochemical smog requires hydrocarbons (in the form of gasoline), solar radiation (reaching the surface as sunlight), and the various nitrogen oxides (NO_x). Nitrogen dioxide forms when NO interacts with atmospheric oxygen (O_2). The oxygen then splits and forms NO and atomic oxygen (O). This occurs after it absorbs solar radiation. Atomic oxygen and O_2 , then, form ozone (O_3) in the presence of sunlight. Simply put, NO and NO_2 react with hydrocarbons (which are present in relatively large numbers due to exhaust from motor vehicles) and form dangerous and volatile compounds. The end result is a brownish orange haze that can aggravate lung conditions, damage trees and other vegetation, and magnify the greenhouse effect.

Although smog results from vehicle exhaust by-products produced during combustion, the problem is exacerbated under certain meteorological conditions. Typically, late spring to early autumn is the time of year when smog difficulties are worse, as conditions are more conducive to smog formation. Temperatures are warmer, which causes the reactions to occur more rapidly (and gasoline to evaporate more

readily). Additionally, the presence of high atmospheric pressure further adds to the problem, since the calm or light wind present inhibits the transfer and dispersal of pollutants to surrounding rural areas by advection. Hence, summer gasoline blends have to meet lower RVP standards. Both summer and winter blends can be reformulated.

Modification and alteration of gasoline requires an analysis of the type and amount of emissions that would result from various reformulations. To do this, those involved in transportation planning and environmental resource management utilize tools called reformulated gasoline predictive models. These models permit investigations into the outcomes of assorted formulations and give regulatory agencies assessments as to the atmospheric impact of different formulas. A series of mathematical equations are utilized to judge the impact of vehicle exhaust on contaminants released to the air. One example of a reformulated gasoline predictive model is the California Reformulated Gasoline Phase Three (CaRFG3) model, which specifically looks at NO_x , CO, vaporized hydrocarbons, benzene, formaldehyde, and acetaldehyde. The implementation of such a predictive model provides some guidance for refiners. For example, they can determine the compliance of a formulation by using the model; emissions must be less than or equal to California standards.

Despite the benefits associated with reformulated gasoline, some disadvantages and criticisms have been noted. One criticism of using the modified fuel is that these altered blends impact the consumer in the form of higher gas prices. Residents of the areas designated by the Clean Air Act (largely concentrated along the eastern seaboard, California, Texas, and Milwaukee–Chicago) do pay higher prices for reformulated gasoline. Although the smog reduction benefits of modified fuels have been shown to mitigate this problem, some critics suggest that modern automobiles are no longer the pollution-spewing machines of the past. They note that newer cars are equipped with emission control technology and that even standard gasoline is now cleaner than it was in the past. Another criticism has been the potential for reduced gas mileage from oxygenated fuels. However, the EPA has found that the reduction is relatively minor, on the order of 2 percent or less; this results in a general decrease of 2 to 4 miles per gallon (0.85 to 1.7 kilometers per

liter). Driving styles, automobile maintenance, and engine type and vehicle size are far greater influences on fuel economy.

Oxygenation: MTBE and Ethanol

Originally, the EPA required that gasoline be oxygenated, as stipulated by the Clean Air Act Amendments of 1990. To ensure that fuel burns more efficiently, gasoline was blended with oxygenating agents.

Various chemical compounds can deliver oxygen to fuel. One such additive is methyl tertiary butyl ether (MTBE), which is a fossil-fuel product. However, MTBE has been linked to environmental contamination and human health problems. A potential carcinogen, MTBE has infiltrated soils and contaminated aquifers as a consequence of being stored in leaking underground storage tanks (USTs). The EPA regulates USTs. Gasoline is held in underground tanks at fuel dispensing stations; should those tanks leak, groundwater supplies become polluted and ingestion of that water poses risks to humans. As the possibility of health problems associated with MTBE became more known, regulators in the United States have called for and implemented phaseouts of the offending chemical. However, studies linking MTBE to health problems have been inconclusive. Nevertheless, California initially began phasing out MTBE as an oxygenator in 2003. Other states have since followed suit.

Ethanol is another common oxygenating compound, particularly in light of the possible cancer ramifications of MTBE. Also referred to as “bio-ethanol” or “pure alcohol,” ethanol is a fuel formulated from plant materials such as corn or sugarcane. Plant sugars and starches are fermented (broken down from carbohydrates to alcohols), which yields a usable fuel form. In the United States, ethanol is largely derived from corn (maize), owing to its vast grain-based agricultural industry; production is concentrated in the Midwest and Plains states. It is sugarcane, however, that provides the primary source of ethanol in Brazil; this is unsurprising, given the tropical climates that permit cane sugar to be grown. Additional plant sources can be used to generate ethanol, such as sugar beets and wheat. Cellulose (as found in wood and grasses) can also be used to generate ethanol, although with more difficulty. Other ethanol-producing countries include China, Canada, and Australia. Collectively, the European Union is the world’s third-largest producer of ethanol

(as of 2011), trailing only the United States and Brazil. Global ethanol production has been increasing, owing to increased demand for fuel and a rising concern over renewable and sustainable resources (and a move toward energy security among producing nations). Global ethanol use is also increasing. Some countries, like Brazil and the United States, have a relatively long history of using ethanol.

In light of the groundwater contamination issues associated with MTBE, the inclusion of ethanol as an oxygenating agent is increasing. Initially, MTBE was preferred over ethanol, as it is easier to move (and thus, cheaper). Ethanol can corrode pipes and (in the United States) must be shipped from the middle of the country (where it is made) to the consuming populations living largely on the east and west coasts. However, ethanol has since gained favor with the decline in the use of MTBE as an oxygen additive to gasoline.

Fuel mixtures are compounds that blend gasoline with ethanol. One such mixture is commonly often referred to as “gasohol”; this describes a mixture that combines gasoline with a small amount of ethanol. In the United States, the term refers to E10, a blend that consists of 10 percent ethanol added to gasoline. This mixture can be utilized without negative consequences in automobile engines (unlike, for example, E85, which is composed of 85 percent ethanol and 15 percent gasoline and requires engines modified to accept this blend). Other mixtures include E5 and E15. The “E” refers to the percentage of ethanol contained in a fuel mixture.

The use of ethanol is not without controversy. There is concern that utilizing corn for fuel rather than food could lead to substantially higher food prices (that is, ethanol shock) and possible unrest. While this would affect poorer countries disproportionately, livestock producers in wealthier countries would also have to pay higher prices for feed. Corn growers can increase production but often not enough meet the demand for both food and fuel. An additional concern is the impact of ethanol production on climate change. Some evidence indicates that a global move toward ethanol would increase greenhouse gas emissions due to land use changes, although more work is warranted.

Conclusion

The employment of reformulated gasoline is one tool in a multipronged approach aimed at reducing

noxious emissions to the atmosphere. Others include vehicle inspections and emissions tests and the promotion of multiple occupant modes of transportation, such as subsidized mass transit and the installation of high occupant vehicle (HOV) lanes in major thoroughfares. However, setting air quality standards like the NAAQS that can be met (at least partly) by using reformulated gasoline may be more likely to result in cleaner atmospheric environments where automobiles are an important part of the local culture.

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See Also: Air Pollution/Air Quality; Alternative Fuels; Clean Air Act and Amendments; Ethanol; Gasoline Engines; National Ambient Air Quality Standards.

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Gasoline Engines

Gasoline engines have dominated the automobile industry since the popularity of Henry Ford’s mass-produced Model T car in the early 1920s. In the early decades of the 21st century, the gasoline engine is losing ground to more innovative methods of propulsion, although it still is the dominant engine fuel. In 1876, German inventors built the first gasoline-fueled, four-stroke cycle engine, and in 1886 Karl

Benz introduced the first commercially produced motor vehicle with an internal combustion engine. By the 1890s, automobile entrepreneurs had developed motor cars to their modern designs so successfully that the principles of the ordinary automobile gasoline engine have remained the same since then. In 1900, Ransom E. Olds stopped producing steam-driven cars and introduced gasoline-fueled vehicles, and in 1908, when Henry Ford put his affordable mass-produced Model T Ford on the market, the gasoline-powered internal combustion vehicle quickly became standard. Mass production of these cars put vehicles on the market that were modestly priced, easy to maintain, fast and powerful, capable of long-distance travel, and powered by gasoline—a cheap, plentiful, and widely available energy source.

In the 20th century, demand for gasoline spurred petroleum industry growth. Consumption of gasoline soared from a 1919 low of less than 3 billion gallons to approximately 15 billion gallons in 1929, 46.5 billion gallons in 1955, and more than 135 billion gallons in 2002. According to the U.S. Energy Information Administration, in 2011, the United States consumed about 134 billion gallons of gasoline, about 6 percent less than the record high of about 142.38 billion gallons consumed in 2007. In 2013, automobiles were responsible for almost 90 percent of the energy consumed for travel in the United States.

Gasoline Engines as Power Trains

In the mid-20th century automobile entrepreneurs introduced the turbine-powered car, as well as the blanket term *power train* to identify the propulsion systems that move cars and trucks. Power trains include gas engines, diesel engines, battery-powered electric motors, and electric motors powered by hydrogen fuel cells. In 2013, engines were not confined to gas or diesel. Clean-burning engine options proliferated, ranging from domestically produced alternative fuels like biodiesel, ethanol, compressed natural gas, liquefied natural gas, and propane gas. The gasoline engine, which has been widely used for more than a century, is still the undisputed number one power train. Ninety-nine percent of all automobile manufacturers devote enormous research and development budgets to gasoline engines to keep classical gasoline engine technology relevant and viable by enhancing its efficiency.

Many factors contribute to make the gasoline engine the top power train. The tooling, materials, assembly techniques, maintenance, and repair procedures in producing gasoline are conventional and widely understood worldwide. The four-stroke piston-driven gas engine is the basic model used in auto shop and mechanic training classes and the model that students study before moving on to other propulsion methods.

Although gasoline engines contain complex moving parts, their parts are flexible enough to allow their designers freedom to modify them as needed. Gasoline-engine performance may be adjusted for horsepower or torque, more or less fuel economy, and more performance in the lower, middle, or top of the engine's range. This flexibility makes gasoline engines viable in small, medium, or large cars, minivans, crossovers, sport utility vehicles (SUVs), and pickup trucks. Gasoline is easy to find, access, and distribute, with no unusual handling specifications, and it is an energy-dense fuel, with a single gallon containing 33.7 kilowatt hours of chemical energy.

In addition to overwhelming positive factors, the gasoline-powered engine has its drawbacks as well. Practically speaking, the piston-driven gas engine is thermodynamically inefficient. An excessively optimized engine might turn nearly 40 percent of the energy in a gallon of gas into useful propulsion. For modern gas engines, anything above 30 percent is considered acceptable; the rest of the energy is lost as friction and heat.

Gasoline engines need routine maintenance. Lubricating oil needs to be changed, seals need to be repaired, filters need to be swapped or cleaned, and rubber parts and ancillary belts in engines need to be replaced. Because it is produced from crude oil, gasoline is a volatile commodity, with fluctuating prices. In 2011, the United States imported about 45 percent of its petroleum, with Canada and Saudi Arabia being the biggest suppliers. The U.S. Environmental Protection Agency reported that American dependency on oil imports has been falling since 2005.

Ethanol and Gasoline Engines as Power Trains

Ethanol fuels contain less energy per gallon than gasoline, but they are substitutable. The most popular ethanol fuel is E85, which stands for 85 percent ethanol and 15 percent gasoline. Ethanol is easier

to find in the Midwest because of regional proximity to its fuel source—corn and assorted grains, primarily—but farm waste may also be an ingredient. The federal Renewable Fuel Standard program guarantees ethanol must be blended into standard gasoline, with formulas including E5 (5 percent ethanol and 95 percent gas), and E10 (10 percent ethanol and 90 percent gas, and E15 (15 percent ethanol and 85 percent gas). E0 ethanol is 100 percent gas. Ethanol might help reduce America's dependence on foreign oil.

On the negative side of the equation, a unit of ethanol contains less specific energy than a unit of gasoline, and the alcohol in ethanol can damage the engines and fuel systems of older vehicles if the ethanol mix is powerful enough. Modern vehicles are designed to tolerate at least up to E10 blends satisfactorily, and vehicles accepting E85 are normally designated as flex-fuel ready. When running on E85 ethanol, an engine is generally downgraded in its Environmental Protection Agency (EPA) fuel economy ratings because it produces less energy per gallon.

The Environmental Impact of the Gasoline Engine

After Henry Ford and other entrepreneurs mass-produced the automobile, gasoline engines and increased fossil fuel production poured toxic chemicals into the atmosphere. Adding many thousands of cars on the road after World War II increased the spread of air pollution, added more and newer pollutants, and threatened many major cities with smog, inversions, and polluted water.

Oil production and gasoline, one of its significant by-products, have had the most significant environmental consequences. The technical limits of the gasoline engine and the massive scale of automobile production have created devastating pollution. In 1955, Congress passed the National Air Pollution Control Act to stimulate air pollution research, but the role of automobile emissions and the gasoline engine in the pollution story took several years to evaluate, and it is still being addressed in the 21st century.

The various components of the gasoline engine, individually or together, are a health hazard to people and the environment. Auto emissions can cause headaches and contribute to lung cancer, emphysema, and respiratory and cardiovascular problems.

They modify weather conditions, damage vegetation, and erode rubber, textiles, dyes, and other materials.

In 1923, gasoline makers introduced another toxic substance, tetraethyl lead, as a gasoline additive, which added another threat to human health. During the decades of the 1960s, 1970s, and 1980s, thousands of automobiles burned huge quantities of gasoline, depositing lead on the soil to be tracked into houses across America. Infants and children ingested the lead, which contributed to nervous system problems, including hyperactivity and hearing loss. Lead does not break down once it is released into the air, and between the 1920s and 1986 when it was finally phased out as a gasoline additive, gasoline engines emitted 7 million tons of lead across the United States.

Oil Companies and Gas for Gasoline Engines

Petroleum products are vital to automobile manufacturing and use, so the environmental effects of drilling, transporting, and refining oil play an important role in the equation between the automobile and the environment. Companies that drilled for and produced oil did not match their success with foresight and restraint in producing and marketing it. Greed, waste, and disregard for conservation measures dominated the oil industry, although in the early 20th century some states passed conservation laws in an attempt to cope with the more harmful oil industry practices. While state and federal authorities were concerned with potentially running out of oil, they ignored oil field waste, pollution, and other environmental problems. Congress attempted to address oil field problems and pollution, but oil-producing states vigorously resisted. Congress did successfully pass the Oil Pollution Act of 1924, which attempted to curb oil discharges from shore plants and ships. The act featured weak enforcement provisions and dealt only with oil-burning vessels dumping fuel at sea.

After World War II, states and the federal government attempted to deal more successfully with gasoline and oil production pollution. Beginning in 1957, small imported cars began to invade the U.S. market while American automobile manufacturers concentrated on producing bigger vehicles with larger engines. GM, Ford, and Chrysler, the Big Three American manufacturers, did not believe a large market existed for small cars, and as long

as gasoline remained abundant and cheap, they continued to produce larger, more powerful automobiles, basing their long-range planning on larger gasoline engines. High-compression engines produced greater horsepower and quicker acceleration for highway travel, and automatic transmissions made driving easier. The side effects of more cars, bigger engines, and automatic transmissions were loss of fuel economy and increased air pollution.

With the exception of California, which led the way in emissions control legislation, the states combated automobile emissions slowly. The 1963 Clean Air Act for the first time gave the federal government limited enforcement power over interstate pollution. The Motor Vehicle Air Pollution Act of 1965 produced national standards comparable to California law, and in 1967 the federal government passed the Air Quality Act, the first piece of federal legislation designed to control lead emissions. By 1966, automobiles and other motor vehicles contributed more than 60 percent of the pollutants in the atmosphere across America, and in 1968 hydrocarbon emissions came under federal jurisdiction.

By the 1960s, some states and the federal government argued persuasively that further pollution by gasoline engines threatened the economic development of the United States. World attention turned to the problem in March 1967 when the supertanker *Torrey Canyon* ran aground off the English coast, spilling most of its 120,000 tons of crude oil into the sea.

On January 28, 1969, a Union Oil well exploded off the Santa Barbara coast in California, ultimately leaking 235,000 gallons of oil into the ocean and further underscoring the need for environmental protection legislation. Congress tightened leasing regulations and pronounced offshore operators liable for cleaning spills. The dramatic events of the Union Oil spill helped encourage the growth of the modern environmental movement and pressured the federal government to pass the 1969 omnibus environmental law, the National Environmental Policy Act (NEPA), but even after it passed, many environmentalists believed that the law had little substance.

In the 1970s, the major environmental battle affecting gasoline engines focused on the Alaska pipeline. In 1968, Atlantic Richfield (ARCO) struck a massive oil field estimated at 4.8 billion barrels

at Prudhoe Bay, Alaska, and soon supporters were clamoring for a pipeline to run 800 miles from Prudhoe Bay south to the port of Valdez. Environmentalists opposed the pipeline on the grounds that it would destroy pristine wilderness, but the 1973 oil embargo undermined their position. In 1973, Congress passed the Trans-Alaska Pipeline Authorization Act and the first oil flowed through the pipeline in 1976. The oil tanker *Exxon Valdez* collided with a reef in Prince William Sound in 1989, splitting open and discharging thousands of gallons of crude oil into Alaska's coastal waters. The accident surpassed the Santa Barbara spill and fueled the continuing debate over the pipeline and other exploitation of Alaskan oil.

The concerns about environmentally harmful accidents, dissatisfaction with existing federal laws, and indifferent state enforcement of laws protecting the environment provided the impetus for the 1970 Clean Air Act Amendments. The most stringent air pollution laws ever passed in the United States, the Clean Air Act Amendments dealt with auto emissions and stationary pollution sources. An amendment to the 1970 Clean Air Act provided further reductions in emissions and authorized the Environmental Protection Agency (EPA) to set emissions standards for new automobiles and other motor vehicles.

A reluctant automobile industry and the energy crisis of the early 1970s created a difficult climate for the Clean Air Act Amendments. The 1970s amendments provided that the EPA could grant a one-year delay in meeting the more stringent environmental standards if the automobile companies made the effort to meet the new standards. Some critics questioned whether the automobile companies had acted in good faith because they used the research and development work of independent companies instead of using their own laboratories and personnel for emissions control technology.

The Clean Air Act Amendments of 1990 substantially revised the 1970 and 1977 acts, with two of the 11 titles particularly focused on transportation. The acts involved a plan to classify cities according to the severity of their emissions problems and how well they met the earlier standards. The new law also established more stringent emissions standards for automobiles and a few trucks for model years 1996–2003. California and some other states were already attempting to

tighten exhaust standards, which the new law supported, but the administration of George H. W. Bush resisted more stringent exhaust standards like California's 1996 Phase II. Instead, the Bush administration promoted new fuels like reformulated gasoline, methanol, ethanol, and natural gas, and the introduction of clean cars in cities with the worst ozone problems. The oil and automobile industries opposed the clean fuels and clean car strategies, but they accepted a diluted version of the law instead of being forced to accept laws similar to California's Phase II exhaust standards.

The automobile and oil industries continued to resist tougher standards for clean air, while the public endorsed clean air but resisted carrying the burden of responsibility through higher costs and reduced automobile performance. Americans still cherish the automobile powered by a gasoline engine.

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See Also: Diesel Engines; Electric Vehicles; Environmental Impacts; Gasoline, Reformulated; Health Issues; Hybrid Automobiles/Hybrid Electric Vehicles; Hydrogen Fuel; Lead Pollution; Transportation, Economics of; Trucking Industry, Economics of.

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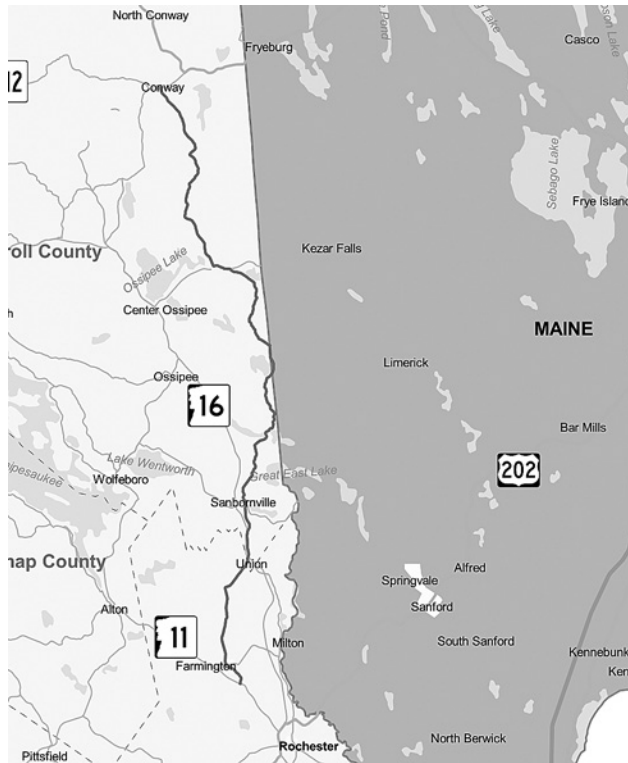
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Geographic Information Systems in Transportation

Because of the spatial separation of resources and services between where they are located and where they are needed, it is necessary to move goods, people, and information among different locations in order to meet various needs in daily life. Transportation therefore is an essential part of human society and is geographical in nature, in that it must deal with not only locations but also interactions among different places. Geographic information systems (GIS), which are computer systems for managing, analyzing, and visualizing geographically referenced data, can offer a useful environment to integrate spatial and nonspatial transportation data in support of transportation planning, operation, maintenance, and evaluation. Such use of geographic information systems to address various transportation-related issues is known as geographic information systems in transportation (GIS-T).



This map of New Hampshire's Route 153 uses geographic information system data from the U.S. Census Bureau, the National Highway Planning Network, and the National Atlas.

Transportation was among the earliest fields to make use of geographic information systems. GIS can be thought of as a computer database that consists of different map layers (for example, land use map layer, transportation network map layer, population census tract map layer, traffic analysis zone (TAZ) map layer, among others) showing various characteristics at different locations in a study area. Query functions can then be used in GIS (for example, what is the land use type at a particular location? or which road segments have an annual average daily traffic above a specific level?) to answer questions.

In addition, GIS offer a set of spatial analysis functions to answer questions related to locations and spatial relationships. For example, a half-mile buffer zone can first be generated around each subway station and then the buffer zones overlaid with a land use map layer to derive land use characteristics around individual subway stations. The shortest path function can also be used to find the best route for traveling from one location to another location on a transportation network. Some basic

GIS-T analysis functions are available to the general public through Internet applications, such as Google Maps. Another advantage of using GIS in transportation is the ability to visualize the data and analysis results in a map format. Since GIS include a database of spatial and attribute data along with a set of mapping functions, they offer useful mapping capabilities beyond what computer-aided drafting (CAD) software products normally deliver. Many transportation agencies therefore have used GIS as the main software environment to manage their data for mapping and analysis purposes.

Evolution of GIS-T

Transportation and GIS have developed as two separate fields with their own specific focuses. Transportation professionals focus on the best ways of meeting the needs of transportation planning, management, operation, maintenance, and evaluation, while the GIS field attempts to address the needs of managing, analyzing, and visualizing spatial data in support of a wide range of application fields. It therefore should not be assumed that all transportation problems can be properly addressed in a GIS environment. In fact, GIS in transportation has evolved over time and will continue to evolve as new transportation challenges surface and new technologies become available.

Because transportation serves as an important map layer in many GIS applications ranging from urban to economic to environmental issues, the DIME and TIGER files showing streets and highways throughout the United States (released by the U.S. Census Bureau in 1980 and in 1990, respectively) provided critical momentum to facilitate GIS applications in transportation and other related fields. The American Association of State Highway and Transportation Officials (AASHTO) started its GIS for Transportation Symposium in 1987, and GIS activities have grown in both the transportation research and application communities since the 1990s. Michael Goodchild characterizes the GIS-T evolution into three stages: the map view, the navigation view, and the behavioral view. The map view takes a static approach with an emphasis on transportation data inventory and description. The navigational view focuses on the data representation of network connectivity and planar topology along with time-dependent attribute data. The behavioral view employs Torsten Hägerstrand's time geography concepts of dynamic

movements of individual trajectories in a space-and-time context.

With the modern location-aware technologies, such as the Global Positioning System (GPS), Wi-Fi positioning system, radio frequency identification (RFID), and mobile phone tracking, it has become feasible and affordable to collect large volumes of tracking data of individual vehicles, shipments, and/or people. Coupled with rapid advancements in information and communication technologies (for example, the Internet and mobile phones), important changes have been observed in spatial and temporal patterns of both human and freight movements. For example, the just-in-time (JIT) practice introduces important changes to where and when products are manufactured, stored, and delivered.

Various real-time monitoring and communication devices installed for intelligent transportation systems (ITS) provide continuous data streams that are used to control traffic flows, respond to emergency situations, inform the public, and/or conduct studies to improve transportation planning and design tasks. Moreover, due to the increasing activities carried out on the Internet, such as e-shopping, e-commerce, e-government, online education, and online social networks, along with the increasing use of online applications of smartphones and other mobile devices, human activities and interactions have exhibited changing spatial and temporal patterns. For example, a customer now can place an order at Amazon.com any time of the day and the item is shipped to the customer's location instead of the customer having to make a trip to a retail store. These changes have important implications for travel demands and traffic patterns.

Since GIS traditionally focus on spatial data represented as static snapshot map layers, such dynamic and mobile data sets present major challenges to GIS-T, which now must be able to effectively and efficiently manage the data in order to provide insights on movements, interactions, changes, and processes in a spatial and temporal context. It can therefore be expected that GIS-T will evolve toward an environment that can better represent, analyze, and visualize dynamic and mobile data in addition to the conventional static data.

What Is Special About GIS-T?

Data representation is the core of GIS. For GIS-T, it is critical to properly represent different types

of transportation data, such as transportation networks (for example, highway network, rail network, transit network), transportation features (for example, traffic sign, median, bus stop), and traffic data (for example, traffic volume, traffic accident, bus schedule). A transportation network is often represented as a set of links interconnected at a set of nodes. Transportation features can be represented as stand-alone GIS map layers, such as a point map layer showing the locations of bus stops or a line map layer showing the locations of medians.

A disadvantage of representing transportation features in separate GIS map layers is that they are not directly associated with their corresponding transportation networks. The transportation community therefore has developed linear referencing systems (LRS) to record the locations of transportation data along a linear transportation route. For example, one can record the location of an on/off ramp or an accident at a specific milepost (for example, milepost 373) on an interstate highway (for example, I-40) in Tennessee. This type of one-dimensional measurement system is different from the conventional two-dimensional Cartesian coordinate system used in GIS. This has prompted the GIS-T to develop a dynamic segmentation data model to accommodate linear referencing data.

Transportation data also frequently deal with traffic flows between a set of origins and a set of destinations, which are represented as origin–destination (OD) matrices. GIS, however, are mostly based on a relational database management system that cannot properly handle OD matrix data and matrix operations. A comprehensive GIS-T therefore should support multiple data models that are required by different transportation applications.

Another requirement of GIS-T is to support various transportation analysis needs. Transportation agencies are responsible for a wide range of tasks, such as transportation system management, infrastructure planning and design, travel demand analysis, transit service, and environmental impact assessment, among others. Each of these tasks has its specific data and analysis needs. For example, traffic engineers may need to look at the design of individual traffic lanes whereas transportation planners often represent roads as centerlines. Also, most network analysis functions, such as the shortest path finding algorithm, require only topological

relationships among the links and nodes in a network and do not need to know their specific locations or exact geometries.

Furthermore, there exist many kinds of transportation analysis methods and models, including spatial interaction models, routing problems, network flow models, facility location problems, and environmental assessment models. It is necessary to integrate these methods and models with GIS in order to support various GIS-T applications. However, many of these analysis functions are not available in general-purpose commercial GIS software products. It is a common practice to couple transportation analysis software with GIS software through some forms of data exchange to take advantage of both systems.

GIS-T to Meet Transportation Challenges

Although human mobility has improved significantly due to technological advancements over time, there exist a number of major challenges in transportation. For example, it is not sustainable to rely on fossil fuels as the main energy source for transportation due to their nonrenewable nature and contributions to air pollution and climate change. Traffic congestion in urban areas is getting worse. Transportation infrastructure is aging and governments often do not have adequate finances to properly maintain or replace them. Safer transportation systems are needed to reduce traffic fatalities and accidents. In addition, major natural disasters and terrorist attacks in recent years have revealed the weaknesses in U.S. transportation systems in terms of emergency response and system security.

How can GIS-T be used to help address these transportation challenges? This is what some researchers are focusing on to demonstrate the relevance and value of GIS-T. For example, GIS could be used to assess the suitability of adopting alternative energy sources (such as solar, wind, or biofuel) in different regions of the world. Modern tracking technologies could also be used to gain insights on human mobility patterns and design transportation systems and services that would better meet their spatial and temporal mobility needs. Furthermore, GIS could help us prepare evacuation plans in response to natural disasters or emergency situations. However, it should be kept in mind that GIS per se cannot solve these transportation challenges. It requires people with application domain

knowledge working with GIS professionals to tackle these transportation challenges. This is what GIS-T is—an integration of transportation with geographic information systems that can benefit and advance both fields.

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See Also: Activity-Based Models; Environmental Impacts; GPS; GPS, Automobile; Health Issues; Intelligent Transportation Systems; Travel Demand Forecasting.

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Global Economic Centers

When studying transportation, it is critical to know where people are going. One way to predict where people are going, or at least one stop on their trip, is to identify the great global cities that act as the world's economic and cultural activity centers. Current global financial centers include London, New York City, and Hong Kong. In addition to being the financial centers, these great cities are also the centers for culture and learning. When looking at these cities on a map, one cannot help but notice certain trends. Most obviously, the current financial centers tend to be capital cities of former colonial powers or regional hubs for those colonial powers. Sociologists have studied issues surrounding these trends by examining theories surrounding colonialism and economic dependency. Three up-and-coming global cities are the Asian cities Beijing, Shanghai, and Taipei. Up-and-coming cities tend to be located in Asia, and many of them tend to have a past or present relationship with China.

Current Global Powers

Financial success is one of the most basic and commonly used metrics for understanding the prosperity of a city. For this reason, the financial analyses by credible organizations of global cities can be used to compare them in terms of not only finances but also culture, travel, and infrastructure. The world's global financial centers have been identified by surveys of influential globalist organizations, such as the World Bank. These studies compare the people, business environment, market access, infrastructure, and general competitiveness of these cities. By these metrics, London, New York, and Hong Kong have been identified as the world's three most influential cities.

London was first settled as part of the Roman colony of Britannia and has been a major settlement for over two millennia. London is by most every measure the greatest financial city in the world. As the capital of the United Kingdom, it was the birthplace of the Industrial Revolution, center of the former British Empire, and has been a world capital ever since. London is the largest urban zone in both the United Kingdom and the European Union. In addition to being an economic and political capital, London is also a world cultural capital, containing four world heritage sites. Additionally, it is a tourist, transport, education, and media center; London is truly a world capital in every sense of the word.

New York City is the most populous city in the United States. The city hosts arguably the most advanced commuter system in the United States, and possibly the world. New York's transit system integrates advanced subway, bus, and highway systems. While New York is not a political capital in the proper sense of the word, it is the home of the United Nations as well as a major finance and culture center. In terms of long-distance travel, most surveys show New York is the destination of choice for foreign visitors to the United States and the gateway for immigration for the East Coast.

Hong Kong entered the global scene when it became a British colony after the First Opium War in 1842. Hong Kong is located within (what is today) the Special Administrative Regions (SAR) of the People's Republic of China. Hong Kong became part of China in 1997. During this transition, the city-state was able to maintain a degree of sovereignty due in part to its financial success.

This eastern city with its expansive skyline and deep natural harbor is also one of the most densely populated spots in the world. Hong Kong boasts a major capitalist economy with low taxation rates and its own currency, which remains independent of that of the People's Republic of China.

Emerging Global Activity Centers

In this ever-changing world, it would be both arrogant and foolish to discount those cities that are not yet global capitals but soon will be. The majority of these up-and-coming cities are in Asia. Three examples of up-and-coming global cities are Beijing, Shanghai, and Taipei.

Beijing is an ancient city that, aside from its recent financial prosperity, is known for its palaces, temples, gardens, tombs, walls, and gates. Once known in the Western world as Peking, Beijing is the capital of the People's Republic of China. Beijing is located in northern China and is the second largest Chinese city by urban population. As the capital, Beijing is China's political, cultural, and educational center. Due in part to its importance to the national character, Beijing serves as the major hub for the national highway, expressway, railway, and high-speed rail networks. In fact, Beijing Capital International Airport is the second busiest in the world by passenger traffic.

Like Beijing, Shanghai is also a popular tourist center due to its historic landmarks and cultural significance for the Chinese people. Shanghai is the largest city by population in the People's Republic of China. Shanghai is a city of global influence in commerce, culture, finance, media, technology, and transportation. Shanghai has been a major administrative, shipping, and trading center in the Eastern world for centuries. With the rise of China as a global power, Shanghai is quickly becoming a major financial center on a global scale, boasting the busiest container port in the world.

Taipei is the capital of Taiwan (also known as the Republic of China). Taipei became the home of the exiled ruling government after being defeated by the Communists in the Chinese civil war. As the capital of Taiwan, this port city is the political, economic, and cultural center of that small nation. In terms of transportation, Taipei is a hub for railways, high-speed rail, highways, airports, and bus lines. These transit lines connect Taipei with all parts of the island.

Social and Spatial Divisions

A little bit of global awareness will tell you that economic inequality around the world is massive. For this reason, economic activity centers are not evenly distributed around the world. A significant portion of these global inequalities can be attributed to the legacy of colonialism. During this system, powerful European nations dominated the rest of the world through exploitative trade relationships. Though existing remnants of these relationships do not help dissipate global inequality, sociologists contend that much of the world's existing inequality can be accounted for by dependency theory.

Dependency theorists contend that certain nations continue to grow by exploiting other nations for the benefit of the exploiters. This theory is given credence by the growing share of global resources accumulating in certain countries while others suffer. Dependency theorists divide the world into three categories: core nations, semiperiphery nations, and periphery nations. Core nations are those nations that have maintained power after giving up a degree of it after the colonial area. They tend to have service- or technology-based economies. Core nations also make a great deal of profit from abstract financial products that rely on the production of periphery and semiperiphery nations.

Examples of core nations include Canada, the United States, France, Japan, and the United Kingdom. Semiperiphery nations are those countries that maintain a degree of independence from the core but are still not at the center of world commerce. Examples of semiperiphery nations include the People's Republic of China, India, Ireland, and Mexico. Periphery nations are many of those that were once referred to as the "third world." They possess underdeveloped economies and infrastructure. Often they derive the majority of national income from the export of natural resources, with little industrial or technology economy. Examples of periphery nations include Afghanistan, Bolivia, Chad, the Philippines, and Vietnam.

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See Also: Business Travel; Economic Development; Globalization; International Travel.

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Global Positioning Systems

See GPS and GPS, Automobile.

Globalization

Globalization refers to the factors that interconnect various locations of the world in ways that make the world more accessible for business, travel, and cultural exchange. Globalization is often thought of as making the world smaller in terms of reducing the difficulty of interacting with distant peoples, economies, and cultures. Factors that have led to globalization include the increasing ease and relative decrease in the cost of travel, access to low-cost and effective communication, the strengthening of once-weak economies, growth of multinational corporations, ease of monetary transfer through the international banking system, and the ability of the transport industry to move goods in an increasingly efficient, expedient, and safe manner.

Another crucial factor is the increased trade between nations. This is because of decreased

tensions between some nations and trade agreements entered into by many nations. The use of cheap labor in some countries to produce the goods that will be consumed in nations with more expensive labor costs is at the heart of the nexus between globalization and transportation.

One of the major impacts of globalization has been the rapid growth of international trade. Japanese cars are now often made in America. U.S. carmakers import many components for their cars from other nations. These American carmakers are even assembling their cars in other countries, for example, Ford and its Mexican assembly plants. Countless American companies like Walmart contract with companies in countries with a cheap labor supply and import goods made abroad to be sold in the United States.

In countries like Vietnam, Indonesia, China, and even Haiti, residents are provided work to make products that are shipped around the world. With the emphasis of organizations like the World Trade Organization (WTO) and the General Agreement on Trade and Tariff (GATT), trade among many of the countries in the world has dramatically increased. This increase in international exchange is made possible, in large part, by the modern transportation system.

Probably the most dramatic development in transportation of goods as it relates to globalization was the advent of container shipping. Containers are metal boxes that closely resemble the trailer portion of a tractor-trailer truck. Prior to the use of containers, goods had to be loaded on trucks or trains, transported to a port, unloaded, and then reloaded onto the ship. This process had to be duplicated in reverse on the receiving end. The manual labor of longshoremen at the docks was intense and added greatly to the cost of shipping.

Using containers, the manufacturer is able to load a container at the point of manufacture. The container is then loaded onto trucks or trains, and sometimes on barges, and taken to the port, where it is quickly loaded by crane onto a container ship. On the receiving end, the process is just as efficient. Whereas before the use of container shipping a freighter might be in port for multiple days to be unloaded by longshoremen, today a container ship can be offloaded in just a few hours. One of the factors necessary for efficient trade between countries is the speed of transport, and

container shipping has greatly reduced the time for shipping goods.

Intermodalism

With globalization has come a dependence on intermodalism. Intermodalism is the use of different modes of transport without having to unload and reload the goods when a different mode is to be used. Containers can be taken by truck to a rail yard and quickly loaded onto a flatcar. Trucks or trains can deliver the containers to a port where they can efficiently be loaded onto a ship. Without intermodalism the rapid growth in trade would have been hampered by the lengthy and expensive process of loading and reloading the goods each time the mode of transport was changed.

While the major economies of the world have been able to build the port facilities necessary to handle container ships, there are poor countries that have not been able to provide the ports that are compatible with container ships. These countries find themselves at a major competitive disadvantage.

The interdependence of countries' transportation infrastructures has been made very evident in a globalized world. Brazil has become a major grain exporter to the world. As such, it becomes a competitor with grain producers in the grain belt of the United States. Because Brazil is on the eastern coast of South America and because that coast extends out into the Atlantic, Brazil may have a competitive advantage in getting grain to the markets across the Atlantic. Grain from the United States has to move down the Mississippi River and be put through a number of locks that are limited in size. This forces the shippers to move their barges through the locks a few at a time. When a completed tow is through the locks, they are tied together again and taken down the river to the Gulf of Mexico and then on to market. For this reason, some are pushing the U.S. Army Corps of Engineers to build new and larger locks that will make it possible for multiple barges to get through the locks more quickly.

The Panama Canal is now in the process of being enlarged to make it possible for more ships and larger ships to go through the canal. Larger ships have been forced to take other routes. When the expansion is completed, larger ships will be bringing goods to the United States. The problem is that

many ports are not equipped to handle the larger ships. Also, some shipping channels, like the Mississippi River, will need deeper dredging to accommodate the ships that will have a deeper draft.

Air transport has become cheaper and more available as planes have grown in size and are being made more fuel efficient. Perishable goods, like cut flowers, can now be supplied to the world market by plane. There has also been a growth in the shipment of packages and goods by international shippers who use aircraft for their long-distance shipping. Companies like UPS and FedEx now have international routes.

As environmental concerns receive more attention from the world community, the transport industry has had to give much more attention as well. After the environmental damage done by oil tankers that sank or had a breach in their hull, shipbuilders were asked to provide ships that were less likely to do damage. Building ships with double hulls was one of the solutions.

The role of fossil fuel is an increasingly important issue in transport and globalization. China is importing more oil. This has led to an increase in the cost of fuel. The United States is looking for alternative fuel sources at the same time that it increases its domestic crude oil and natural gas production. These factors have an impact on where in the world oil has to be shipped.

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See Also: Canals and Locks; Containerization/ Container Shipping; Dredging; Intermodal Freight Transport, Technology and; International Customs and Duties; International Travel; International Waters; Supply-Chain Management; World Container Ports.

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GPS

The movement of goods, services, and people across the United States and global transportation infrastructure have evolved tremendously over the past two decades, due in part to technological advancements and the commercial and civilian availability of the Global Positioning System (GPS).

The GPS, a U.S.-owned utility, is a dual-use, satellite-based system that provides accurate positioning, navigation, and timing services to users around the world. While GPS was at one time only used by the U.S. military and defense support agencies, free and open access to GPS data by the civilian sector and commercial industry has significantly changed the landscape of the global information and transportation infrastructure—improving the way people and goods are moved around the globe.

Development of the GPS began in 1973 under the U.S. Department of Defense to support critical military operations but did not gain full operational capability until early 1995. In 1996, President Bill Clinton established GPS as a dual-use system to support both U.S. military and civilian applications, signing the U.S. Global Positioning System Policy on March 29 of that year.

The policy established the GPS as a national asset and opened its use to the civilian and commercial sectors. One of the major goals of this policy was to promote the safety and efficiency of the U.S. transportation sector, influencing how the transportation infrastructure was developed and used.

In 1998, Vice President Al Gore announced a series of modernization efforts to improve the performance of GPS data provided to civilians and commercial industry partners, including increasing the availability and responsiveness of the system. By 2000, President Clinton, with authorization from the U.S. Congress, announced the decision to stop degrading the accuracy of GPS data for civilian use, making the location data up to 10 times more accurate.

This measure signaled the United States' last formal policy step in the modernization initiative, thereby ensuring private-sector investment into GPS services and technological advancements and encouraging civil, scientific, and commercial users' integration of GPS data into their applications for use by the public.

System Operation

The system is owned and operated by the U.S. government, with the Interagency GPS Executive Board overseeing the system's overall management, including maintaining and improving upon the system's performance and accuracy.

The location and timing data for the GPS is provided by a constellation of satellites and respective navigation payloads that produce GPS signals. These are linked to GPS ground stations and command and control facilities operated by the U.S. Department of Defense and the Standard Positioning Service (SPS), which services the civilian and commercial sectors.

The GPS system consists of space and control segments, maintained and operated by the U.S. Air Force, and a user segment. The space segment represents a constellation of 24 satellites more than 10,000 nautical miles above the Earth, each orbiting the planet twice during a 24-hour period. The control segment consists of monitoring stations that update and correct errors in navigation data received from the satellites, and the user segment is represented by receivers that pick up these signals from the orbiting satellites.

Four satellites are used at any one time to identify the precise position of a GPS receiver on Earth, with the first three satellites narrowing the possible range of locations and the fourth confirming the precise location of the receiver, which can range in accuracy from 3 to 15 meters, depending on the device. The information provided by the GPS includes longitude, latitude, altitude, and time; each satellite contains multiple atomic clocks that contribute precise time data to GPS signals picked up and decoded by GPS receivers. Many economic activities, such as communication and financial networks and electrical power grids, rely on GPS for this precise timing information in order to synchronize operations and improve efficiencies. The free availability of GPS has enabled cost savings for many companies that depend on GPS to provide this capability.

In addition to the current GPS civilian service, the United States has been working to implement additional civilian signals, the first of which was launched in 2005. The access to these new signals by the civilian sector will result in increased accuracy, availability, and integrity for all users, as well as increased robustness for safety of navigation (both air and maritime) and increased interoperability



The Air Force launches the fourth of a series of eight GPS IIR modernized satellites into space from Cape Canaveral in Florida on a Delta II rocket, October 17, 2007. The U.S. Air Force provides at least 24 satellites for GPS at most times.

between GPS and international satellite navigation systems. These signals are being phased in incrementally by the U.S. Air Force as it launches new GPS satellites to replace aging assets. The U.S. Commerce Department estimates that the additional signals for civilian use will result in more than \$5.5 billion in economic benefit by 2030.

Because of the amplified use of GPS worldwide, the United States has seen an increase in the impact of GPS on the following areas: aviation, agriculture, environmental restoration and protection, marine navigation, public safety and disaster relief, rail transportation, civilian recreational uses, roads and highways, space endeavors, surveying and mapping, and timing.

Civilian Use

With the expansion of GPS to the civilian and commercial sectors, demand for equipment and capabilities to access the data also have grown. This growing demand supported a response by the U.S. commercial industry to develop personal-use GPS data-receiving equipment and services aimed at providing enhanced GPS services to consumers. This free and open access led to a plethora of technological applications affecting every aspect of modern life. GPS data-receiving units and devices can now be found in cars, cell phones, wristwatches, shipping containers, and even ATMs.

Additionally, industry has seen direct economic impacts through established cost savings and boosts to productivity because of the availability of GPS data. Market research suggests that annual GPS data-receiving equipment revenues related to commercial, consumer, and military customer bases in North America alone have averaged more than \$33 billion during a five-year period (2005–10).

When installed in a car for personal use, a GPS data-receiving unit provides information to the driver about the car's location and the best travel routes to any given destination. To do this, GPS information is combined with a geographic information system (GIS), which helps align the precise geographic coordinates with known digital maps already uploaded to a GPS data-receiving device. By providing a visual, map-based format, a driver can decide on an optimum route and can adjust that route according to traffic conditions and preferences; the device continually recalculates the route based on the driver's changing position and updates and displays the information required by the driver. Many devices now include additional details, such as services along the chosen route and narratives to guide drivers through directions to their destination.

GPS data receivers can also track the distance a vehicle travels per trip and record the associated driving activity, such as destinations and routes taken. Because of these advantages, GPS technology is increasing in popularity among vehicle owners, with many car manufacturers opting to provide standard GPS data-receiving functionality in newer product lines.

Despite these advantages, some problems with blocked reception still exist, for example in landscape conditions such as mountains, high buildings, tunnels, urban canyons, or thick-branched

trees. However, technology that utilizes GPS data is advancing very quickly, and newer devices are being developed every year to correct problems and focus on improved accuracy, better reception, and even more user-friendly features.

Recent safety features associated with GPS have also significantly contributed to saving lives by speeding the delivery of emergency services to disabled vehicles and their passengers. This contribution to consumer and travel safety has become an increased priority for the automobile industry, as focus has shifted from meeting basic transportation needs to designing and implementing features that make a vehicle safer to operate, including location services utilizing GPS data to assist emergency services with locating a vehicle in the case of an accident.

The transportation industry is currently studying additional ways to use GPS to help drivers by providing warnings of potential critical situations, such as traffic violations or crashes. Additional research is being conducted to examine the potential for minimal vehicle control when there is a clear need for action, such as the predeployment of air bags, and GPS is vital to the success of this research.

The continuous modernization of GPS and receiving devices has transformed the way typical users travel. The capabilities offered to these users have increased travel options for many, while also reducing issues and improving efficiencies. With this continuous modernization, one can expect even more effective systems for crash prevention, distress alerts and position notification, electronic mapping, and in-vehicle navigation with audible instructions.

Roads, Highways, and Mass Transit

The availability and accuracy of GPS data offers increased efficiencies and safety for vehicles using highways, streets, and mass transit systems. Many of the problems associated with the routing and dispatch of commercial vehicles is significantly reduced or eliminated with the help of GPS data. This is also true for the management of mass transit systems, road maintenance crews, and emergency vehicles.

The U.S. government estimates that delays from traffic congestion on the nation's highway and transit systems result in hundreds of billions of dollars annually in lost productivity. Because of this, federal, state, and local transportation departments responsible for the nation's roads, highways, and mass transit systems are continuing to investigate

and invest in the best ways to use GPS data and systems to increase efficiencies in operations and to promote safety for those in transit.

The GPS enables automatic vehicle location systems and in-vehicle navigation systems that are widely used throughout the world today. By combining GPS position technology with systems that can display geographic information, or with systems that can automatically transmit data to display screens or computers, a new dimension in surface transportation is realized.

When used with GIS, those organizations and agencies can use GPS data and information to monitor the national infrastructure and better allocate resources to fix problems as they arise. For example, many state and local governments rely on GPS data to help monitor transit vehicle activity, including their locations, in order to keep passengers informed on precise arrival and departure times as well as scheduling delays. Mass transit systems use this capability to track rail, bus, and other services to improve on-time performance, and in the case of accidents, to direct support and emergency services to problem locations even if passengers or transit workers are unable to do so.

In addition to its applications in private vehicles and the support of the nation's infrastructure, GPS data is used by commercial ground-shipping companies to speed the delivery of cargo. By using GPS data and devices, companies can track shipping fleets worldwide, record the movement of vehicles associated with those fleets, and control route planning. Using GPS technology to track the movement of freight has improved many companies' logistical operations and their interface with consumers through services such as "time-definite delivery." This capability improves the overall efficiency of those operations, increasing the overall economic benefit to the companies and their consumers.

Additionally, many nations use GPS data to help survey their road and highway networks by identifying the location of features on, near, or adjacent to the road networks. These include service stations, maintenance and emergency services and supplies, entry and exit ramps, damage to the road system, etc. The information serves as an input to the GIS data-gathering process. This database of knowledge helps transportation agencies reduce maintenance and service costs and enhances the safety of drivers on the roads.

The U.S. government credits the GPS with ensuring higher levels of safety and mobility for all surface transportation system users, more accurate position determination to provide greater passenger information, more effective monitoring to ensure schedule adherence, creating a transit system more responsive to transportation users' needs, better location information with electronic maps to provide in-vehicle navigation systems for both commercial and private users, and increased efficiencies and reduced costs for surveying roads.

Using GPS technology to help track and forecast the movement of freight has created a logistical revolution, including an application known as time-definite delivery. In time-definite delivery, trucking companies use GPS data for tracking to guarantee delivery and pickup at the time promised, whether over short distances or across time zones. When an order comes in, a dispatcher initiates a computer function and a list of trucks appears on the screen, displaying a full array of detailed information on the status of each. If a truck is running late or strays off route, an alert is sent to the dispatcher.

Aviation

Another area in which GPS is a vital component of improved operations is aviation. Similar to how GPS data support safety and efficiency of ground travel, GPS assists with increasing the safety and efficiency of flight around the world. With its accurate, continuous, and global capabilities, GPS provides data for seamless satellite navigation services that satisfy many of the requirements of aviation users. Space-based positioning and navigation enables three-dimensional position determination for all phases of flight, including departure, en route, arrival, and airport surface navigation.

New and more efficient air routes made possible by GPS data are continuing to increase, resulting in time and financial savings. For example, research shows that aircraft flying over data-sparse areas such as oceans have been able to safely reduce separation between one another, which allows multiple aircraft to fly more favorable and efficient routes in order to save time and fuel and increase revenue.

As in ground transit applications, the aviation community is also seeing continuous improvements to the modernization and effectiveness of GPS data-based applications and capabilities to support an ever-expanding robust aviation system. Reliance on

GPS data as the foundation for today's and tomorrow's air traffic management system is a major part of many national plans. Aviation authorities are moving forward on initiatives aimed at documenting reductions in flight time, workload, and operating costs for both the aviation service companies and travelers. GPS data also serve as an essential component for many other aviation systems, such as the Enhanced Ground Proximity Warning System (EGPWS), which has been successful in reducing aircraft accidents.

The U.S. government credits GPS with the following benefits to the aviation community: continuous, reliable, and accurate positioning information for all phases of flight on a global basis, freely available to all; safe, flexible, and fuel-efficient routes for airspace service providers and airspace users; potential decommissioning and reduction of expensive ground-based navigation facilities, systems, and services; increased safety for surface movement operations made possible by situational awareness; reduced aircraft delays due to increased capacity made possible through reduced separation minimums and more efficient air traffic management, particularly during inclement weather; and increased safety-of-life capabilities such as the EGPWS.

Maritime

GPS has changed the way much of the world operates and this is also true for marine operations, especially in the areas of navigation and search and rescue. Since GPS data-based applications provide the fastest and most accurate method for mariners to navigate, measure speed, and determine location on the high seas, cargo shipping companies, the fishing industry, and recreation cruise companies have enjoyed the many benefits GPS data brings to their overall operations worldwide.

Oceangoing vessels encounter a variety of hazards as they negotiate the oceans' vast expanses, so navigating open seas in the most economical, safest way possible is highly dependent on the accurate position data provided by GPS data. Ship captains and crews rely heavily on GPS data to understand their ocean vessel's position and speed in order to navigate congested harbors and open waterways. Add the vast array of sea conditions to the mix, and maritime transportation operations become one of the most hazardous forms of transportation on the planet, with a greater risk of accidents and

increased difficulty in supporting search and rescue operations. The need for accurate positioning information becomes even more critical as the vessel departs from or arrives in port.

Additionally, mariners and oceanographers are increasingly using GPS data for underwater surveying, buoy placement, and navigational hazard location and mapping. Commercial fishing fleets use GPS data to track fish migrations and to navigate to potential fishing locations. From a policy standpoint, GPS data has played a role in ensuring compliance with maritime transport regulations and has helped the U.S. Coast Guard cut down on illegal fishing trade and transportation.

An enhancement to the basic GPS signal known as Differential GPS (DGPS) provides much higher precision and increased safety in its coverage areas for maritime operations. Many nations use DGPS for operations such as buoy positioning, sweeping, and dredging. This enhancement improves harbor navigation.

World governments and industrial organizations are also working to develop performance standards for electronic chart display and information systems that pull location and positioning information from GPS and/or DGPS. With the implementation of these standards, these systems continue to revolutionize marine navigation and will help phase out paper nautical charts that can prove to be outdated or inaccurate.

Similar to the GIS and mapping overlays supportive of GPS data receiving devices used in ground transportation, the information provided by the DGPS can also be integrated with radar information and digital nautical charts in an electronic format. This format provides a standard, common operating picture for many commercial vessels, with the opportunity for automatic updates of information. Additionally, GPS information is embedded within a transmission known as an automatic identification system (AIS). An AIS is used for vessel traffic control around busy seaways, which is vital to safe navigation procedures and increases security of ports and waterways by providing greater situational awareness of commercial vessels and their cargo.

An AIS transponder system is capable of communicating ship-to-ship and ship-to-shore by transmitting real-time information on the vessel's identification, location, and cargo. This is possible

due to the vessel's GPS position being embedded in these transmissions, where essential information about its movements and contents can be automatically uploaded to electronic charts and greatly enhance the safety and security of vessels using this system. The capability that comes from combining GPS, DGPS, AIS, and digital chart information serves to increase the efficiency of maritime transport operations along the world's waterways, resulting in reduced risk to vessels and cargo and increased cost savings to the overall industry and consumer base.

The role of GPS is also increasingly in the management of port facilities. GPS technology, coupled with GIS software, is key to the efficient management and operation of automated container placement in the world's largest port facilities. GPS technology facilitates the automation of the pickup, transfer, and placement process of cargo containers

and can track them from port entry to exit. With millions of container shipments moving through port terminals annually, GPS applications have greatly reduced the number of lost or misdirected containers as well as the associated operating costs.

National Transportation Infrastructure

GPS has not only had significant impact on the safety and transportation of goods, people, and services across the world's oceans and the nation's highways, it has also changed the way roads and highways are built, increasing the life cycle of the national infrastructure.

GPS data equipment has helped with the construction industry's productivity by providing accurate machine guidance and measurement technology that improve the accuracy and efficiency of many construction-related functions such as surveying, excavating, grading, subgrading,



A Federal Emergency Management Agency (FEMA) contractor attaches a GPS transponder onto one of a fleet of 300 FEMA disaster relief trailers at the Fort Gillem FEMA Logistics Center in Atlanta, Georgia, August 29, 2006. GPS helps managers of emergency vehicle fleets avoid delays in dispatching emergency services by giving them the ability to effectively identify the location of emergency responders and of police, fire, and rescue vehicles in relation to disaster survivors and others in need.

transportation management, facility delivery, urban planning, and job site safety monitoring.

Activities that once required items such as measuring tapes, compasses, and levels combined with weeks or months of intensive work by teams of specialists are now completed in a matter of hours by a single person with a GPS data receiving device. GPS surveying instruments can make precise measurements without a line-of-sight requirement and work under a multitude of weather conditions. This improves the overall construction process. Additionally, GPS contributes to the more effective management of construction material and equipment, which ultimately reduces costs and inefficiencies. Recent industry surveys suggest that more than 40 percent of civil engineering construction projects have adopted using GPS data receiving devices in the management of construction projects.

For example, GPS antennas are now commonplace on most roadwork equipment and have proven instrumental in improving how the nation's roads are built. Because of the accuracy of these receivers, engineers can ensure that the perimeters set for a particular construction project are more accurately carried out in the way they were designed. This improves the accuracy of the road being built and extends the performance and life of the materials used. For example, precision grading using GPS data in roadway construction projects has proven to reduce workload of construction crews and to increase the overall efficiency of the construction project.

Emergency Response and Disaster Relief

GPS has also become an integral part of modern emergency response systems—whether helping stranded motorists find assistance or guiding emergency vehicles. Knowing the precise location of landmarks, streets, buildings, emergency services resources, and disaster relief sites reduces the time it takes to get to those in need, saving lives in the process, and GPS is vital to informing emergency workers, first responders, and public safety personnel during these emergency and disaster relief operations.

GPS has played a vital role in relief efforts for global disasters such as the tsunami that struck the Indian Ocean region in 2004, Hurricanes Katrina and Rita that wreaked havoc in the Gulf of Mexico in 2005, and the Pakistan–India earthquake in 2005. Search and rescue teams used GPS, GIS, and

remote sensing technology to create maps of the disaster areas for rescue and aid operations and for assessments of damage. These capabilities are also integral to managing and containing the spread of wildfires as well as emergency response to storm damage and flooding in areas affected by such natural disasters. GPS precision information can help play a role in anticipating such events and helping ensure the safe evacuation of people in the affected disaster area, and in management of emergency response resources.

As the international positioning standard for use by emergency and other specialty vehicle fleets, GPS has given managers a quantum leap forward in efficient operation of their emergency response teams. The ability to effectively identify and view the location of emergency responders and of police, fire, and rescue vehicles in comparison with individuals affected by an emergency situation creates a new transportation network in a geographic area and avoids delays in the dispatch of emergency services.

In short, GPS modernization translates into saved lives by delivering disaster relief to areas in a more timely and accurate manner, saving lives and restoring critical infrastructure, providing position information for mapping of disaster regions, enhancing capability for flood prediction and monitoring of seismic precursors and events, and providing positional information about individuals with mobile phones and in vehicles in case of emergency.

Vulnerabilities, Privacy, and Policy Response

Like all radio-based services, GPS is subject to interference, and devices can lose reception due to both natural occurrences like solar flares and human-made causes such as intentional jamming devices. Since 2000, U.S. policy has worked to document these unintentional and intentional vulnerabilities in the U.S. transportation system due to the availability of and access to GPS data and the risks associated with the GPS system being the only means for position determination and precision timing. In addition, the government is currently fielding new GPS signals that are more resistant to interference. As such, many have contended that the GPS system cannot serve as the single source for location information or precise timing data in case of failure and loss of capability for critical applications. Policy members have recommended establishing backup systems and procedures for all GPS applications

where a loss of information or connectivity could result in potential life-threatening situations or major environmental or economic impacts.

As a result of U.S. policy, the U.S. Department of Transportation has worked to establish GPS backup systems or applicable operational procedures to ensure limited impact on the safety of people, goods, and systems in the event of loss of GPS signals or in which applications would be adversely affected. Additionally, the U.S. Department of Transportation has taken an active role in outlining priorities and measures for ensuring that the future navigation infrastructure's use of GPS will fulfill its role as a key element of the national transportation infrastructure. Furthermore, U.S. presidents since the onset of GPS have worked to consistently issue policies that would foster the investment and development of GPS technologies, initiatives, and capabilities for a multitude of peaceful purposes worldwide.

However, with the increased use of GPS and geolocation, or geotagging, technologies and software, many have expressed concern over the potential misuse of this information in respect to an individual's privacy. While current federal statutes do not clearly protect individuals from such misuse, congressional members are moving forward on introducing legislation to deal with these concerns. One such piece of legislation is the Geolocation Privacy and Surveillance Act, or GPS Act, which seeks to establish a legal framework that gives government agencies, commercial entities, and private citizens clear guidelines for when and how geolocation information can be accessed and used. The bill proposes creating a process whereby government agencies must obtain a probable cause warrant to obtain geolocation information in the same way that they currently obtain warrants for wiretaps or other types of electronic surveillance. Additionally, the act would prohibit businesses from disclosing geographic data about its customers without their consent. In March 2013, the bill was reintroduced for consideration by the 113th Congress and has been referred to the Senate and House Judiciary Committees and the House Intelligence Oversight Committee for review.

Similar to the GPS Act, the Online Communications and Geolocation Protection Act contains many of the same provisions and was also submitted to the 113th Congress for consideration.

The stability and transparency of U.S. policy, combined with a long track record of dependable GPS service, have laid a solid foundation for investment and innovation in GPS technology. As a result, the commercial use of GPS technology has flourished, transforming the way Americans live and work today.

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See Also: Aviation, Commercial/Business; Department of Transportation Act of 1966; Freight Transport, Security Issues; Geographic Information Systems in Transportation; Globalization; GPS, Automobile; Traffic Detection Systems.

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GPS, Automobile

The Global Positioning System (GPS), a U.S.-owned utility, is a satellite-based navigational system developed by the U.S. Department of Defense in the 1960s to help U.S. Navy submarines determine their position more accurately. The technology, which triangulates time signals from space using satellites and ground stations, was used exclusively for military purposes until the early 1980s when the Ronald Reagan administration opened the doors to applications in the private sector.

Since then, GPS technology has evolved significantly in both scale and scope and is widely used in smartphones, computer tablets, watches, and vehicles. Some vehicle manufacturers now install GPS data-receiving functionality as part of their onboard computer systems as a standard practice; others offer it as an inexpensive add-on. For vehicles without built-in GPS receivers, there are a host of external device options available to consumers at fairly nominal cost. The ubiquitous nature of products utilizing GPS data and their increasingly in-depth services are changing the way many Americans drive.

Benefits of GPS

GPS satellites orbit the Earth, zero in on Earth-bound transmitting devices through a series of signals, and calculate how long the signals take to arrive. The result of that calculation provides an extremely accurate, real-time estimation of latitude and longitude. That near-pinpoint accuracy has helped dramatically alter the way motorists get around. For many, gone are the days of storing paper maps under the seat, stopping to ask a stranger for directions, or getting dangerously lost because a street sign was passed unseen.

GPS data offers a convenient means to facilitate efficient travel by providing a clear indication to drivers as to where they are and where they are going. Drivers can enter a destination address and, with the click of a button or voice confirmation, start the system calculating an optimal route. Drivers even have the option in most cases to fine-tune the process even further by requesting the most direct route or the one with the least amount of multilane highways or other type of preference. With most models, the GPS data receiver displays the relevant segments of the route in map form, list form, or both on a lighted screen and provides audible directions

at each juncture. If the driver misses a turn, the GPS receiver automatically recalculates the route based on the revised vehicle position. The state-of-the-art technology and user-friendly delivery can help make driving in unfamiliar areas less stressful and distracting.

GPS data receiving technology also helps motorists avoid traffic delays. Some applications using GPS data offer a feature that is capable of monitoring current traffic volume along roadways, giving drivers an opportunity to adjust their route to avoid potentially long delays. Some systems go so far as to indicate which lane to drive in. They notify the driver in advance of an exit or a shift in the road as to which lane or lanes are best to carry on with the designated route. For drivers unfamiliar with a specific major highway system, the visual and vocal cue is another useful convenience feature.

GPS also offers safety benefits. At night and during bad weather, for example, a GPS data-based application alerts the motorist to an upcoming turn or ramp long before the driver is likely to see it. It also works well on low-lit back roads by providing a preview of what is ahead. Many GPS data-receiving devices offer a night-vision version of the viewing screen, which changes automatically in dim-light conditions to ensure optimal visibility



A dashboard-mounted Global Positioning System (GPS) data receiver. GPS data is stored in the servicing company's database and may be passed on to market researchers, who then tie traffic patterns to demographic data from vehicle registration.

of the route and additional key information on the screen. Other common safety features of installed GPS receiver models are hands-free calling in case of emergency and special help buttons that direct the driver to the nearest police station, hospital, or service garage.

In addition, a GPS data device can increase security of the automobile itself. GPS data services that are part of a vehicle's computer system, such as OnStar, offer the ability to instantly map the current location of a vehicle without driver involvement. Its programming inherently records the vehicle's location, speed, route, and even safety features like seat belt use and signaling, making swift retrieval in the event of a theft more feasible. Those same features, however, may make some drivers uneasy. It is disconcerting for some to realize that their movements and the activities they engage in within the privacy of their personal vehicle are being tracked and recorded by the GPS data servicing company even in nonemergency and nontheft situations.

The data obtained by a vehicle's GPS receiver is recorded by the servicing company and stored in that company's database system. That information then may be passed on to market researchers interested in learning about driving habits and travel behavior among certain populations. For example, a company seeking to advertise to a certain consumer group may look to the GPS data to determine the best placement for outdoor advertising billboards based on who is traveling which roads and when. Those traffic patterns are identified by GPS tracking information and can be tied to demographic data based on each vehicle's registered ownership.

The U.S. Department of Transportation has tested the research validity of GPS data collection and found that GPS technologies accurately capture variability in travel behavior across multiple days and offer detailed route selection, spatial location, and travel itinerary information not readily available by other travel data sources.

While GPS technology makes the act of navigation less complicated, it is important that drivers remain alert and responsible. The allure of new technology with interactive touch screens and customizable voice options may be a distraction for some, especially newer drivers and those new to GPS, who tend to look at the navigation screen much more than is necessary. An unsafe habit that many drivers practice—even long-time GPS data users—is entering a

destination or modifying a route while engaged in the act of driving. Some of the newer installed GPS data devices will not allow reprogramming while the vehicle is in motion. For the ones without this safety measure, it is up to the driver to be responsible and pull over or wait until stopped at a light before attempting to modify GPS receiver settings.

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See Also: Automated Vehicle Guidance Systems; Automated Vehicle Location Systems; Automated Vehicle Monitoring Systems; Automobile Culture; Automobile Design; Automobile Trips; Automobiles, Passenger; GPS; In-Vehicle Computers; Transportation Statistics and Databases.

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Gravity Models

The gravity model is a general model used to describe the spatial interaction behavior of social and economic flows. In its various forms, the gravity model has been widely used for several decades in such disciplines as transportation, geography, urban and regional planning, sociology, demography, economics, health planning, and marketing to analyze and predict flows of people, goods, money, etc. In transportation, the gravity model was a

part of a string of models in the U.S. Department of Transportation's urban transportation planning (UTP) procedure used to forecast the flow of people and/or vehicles on every link of a transportation network in order to evaluate various transportation plans. Today, all commercial transportation planning packages include modules to compute gravity models.

While several versions of the gravity model have been given in the literature, in the most general definition of the gravity model, a flow T_{ij} between an origin i and a destination j is written as

$$T_{ij} = A_i B_j F_{ij}$$

where T_{ij} is the expectation, EN_{ij} , of the number N_{ij} of trips between origin i and destination j , that is,

$$N_{ij} = T_{ij} + \epsilon_{ij}.$$

The A_i is called an origin factor, B_j a destination factor, and for most applications are considered to be parameters to be estimated. The F_{ij} is called a separation factor, and for practical purposes, is specified to be

$$F_{ij} = F_{cij}$$

namely, a function of a separation measure c_{ij} . The separation measure c_{ij} may be vector valued, that is,

$$c_{ij} = c_{ij1}, c_{ij2}, \dots, c_{ijK}$$

where each component c_{ijk} is by itself also a measure of separation (for example, distance, transportation cost, travel time). The algebraic form of the function F_{cij} is set to be

$$F_{cij} = \exp k = 1/K \theta^k c_{ijk}$$

where $\theta^k = \theta_1, \theta_2, \dots, \theta_k$ are unknown parameters to be estimated from observed flows. This form is general enough for most applications of interest. Such gravity models are called exponential gravity models and can be readily estimated by maximum likelihood procedures.

Development

Early 20th-century gravity models were developed by analogy with the physical sciences. By mid-20th

century the intervening opportunities model was proposed to derive a model of flows from a different premise. The model assumed (1) that each traveler examines destinations sequentially starting with those closest to him/her and proceeding outward and (2) that each destination is chosen in proportion to the number of opportunities in it by someone who has not already accepted a closer destination. Later research showed that the intervening opportunities model is a special case of the form $T_{ij} = A_i B_j F_{ij}$ above.

In the 1950s and 1960s the gravitational analogy for the gravity model was challenged and a number of changes to the algebraic form of the function F_{cij} were proposed, for example,

$$F_{cij} = \exp(\beta c_{ij}) \quad \text{or} \quad F_{cij} = c_{ij} \exp(\beta c_{ij}).$$

During that time, particularly in transportation studies, the separation measure, c_{ij} , was changed from distance to travel time, and since travel time is usually more sensitive to transportation system improvements, it also facilitated examination of the impacts of such improvements. Another frequently used measure is generalized cost, which is a linear combination of travel time and travel cost.

In the 1960s the gravity model was derived using entropy maximization, and Alan Wilson in his seminal work derived the model

$$\begin{aligned} T_{ij} &= a_i O_i b_j D_j F_{ij} \\ \text{with } O_i &= \sum_j T_{ij} \quad D_j = \sum_i T_{ij} \\ \text{and } C &= \sum_{ij} c_{ij} T_{ij}. \end{aligned}$$

The entropy maximization approach assumed that (a) all microstates (lists of individual trips from all origins to all destinations) are equally probable and (b) the most probable meso-state (an origin-destination trip table) is the one given by the largest number of microstates. Wilson's model is equivalent to the generalized gravity model $T_{ij} = A_i B_j F_{ij}$ above by setting

$$A_i = a_i O_i \quad \text{and} \quad B_j = b_j D_j.$$

In the 1970s T. E. Smith proposed his efficiency principle, which allowed some of Wilson's microstates consisting of longer trips to be less probable than others. As a result, Smith found that the expected flows T_{ij} must be characterized by the gravity model. Subsequently, Smith proposed the

current theory of the gravity model based on axiomatic foundations. The axioms provide both necessary and sufficient conditions for the model to hold. The implication is that such theoretical arguments are a means of formulating a hypothesis that should be tested empirically. A very large number of empirical studies with the gravity model have shown that the gravity model has a sound theoretical basis.

Estimation of Gravity Models

When the number of trips N_{ij} are Poisson distributed, the resulting gravity model has the form

$$T_{ij} = A_i B_j \exp k = 1/K \theta k_{cijk}.$$

Maximum likelihood (ML) procedures are used for the estimation of the parameters A_i 's, B_j 's, and θk 's. Maximum likelihood estimates have desirable asymptotic properties (consistency, efficiency, and asymptotic normality) and are robust to distributional assumptions for realistic departures from the Poisson assumption (note that the multinomial distribution leads to identical estimates with the Poisson distribution). Furthermore, they are essentially unbiased even for a very small sample of flows. It can be proved that under mild conditions the estimated θk 's are unique. The estimates of A_i 's and B_j 's are not unique; however, if one A_i or B_j is chosen to be an arbitrary positive number, the remaining A_i 's and B_j 's are unique under the previous mild conditions.

Specialized statistical software exists that allows gravity model parameter estimation and flow forecasting among several thousands of origins and destinations. In addition, numerical methods exist to estimate asymptotic covariance matrices for ML estimates of gravity model parameters in order to obtain parameter confidence intervals and allow for significance tests.

Transportation Applications

The gravity model is widely used within the UTP framework and its extensions to estimate passenger and freight flows. Within this framework, it is interesting to observe that origin–destination travel times and/or costs (which depend on routes chosen and traffic congestion on the routes) usually become available only after the gravity model has been applied to forecast flows. This difficulty affects only the forecasting phase (not the estimation phase, when one uses base period data for which

travel times can be observed or computed using available information) and can be alleviated by combining the distribution and assignment stages of the process into a single stage.

The gravity model is also used in land use forecasting by extension of the UTP procedure. Since the trip generation and trip attraction phases require as inputs a number of inputs as independent variables measuring intensity of land use, forecasts of these variables need to be made using a land use model. If the land use model used is of the Lowry type, which is basically a gravity model, the gravity model is used to obtain inputs for trip generation, which, in turn, is used as input into a gravity model with the same separation factors.

Another application of the gravity model relates to the aggregation and disaggregation of origin–destination flows from/to a smaller to/from a larger traffic analysis zones (TAZ) system.

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See Also: Destination Choice Models; Equilibrium Modeling; Highway Planning; Origin–Destination Models; Residential Location Models; Spatial Equity Analysis; Transportation Modeling and Planning Software; Transportation Planning; Transportation Studies; Travel Demand Forecasting; Travel Model Calibration and Validation; Trip Chaining; Trip Distribution Models; Urban Transportation Modeling System.

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Green Fuels

Fuels traditionally used to power the transportation sector are derived from fossil fuels such as petroleum. However, fossil fuels have a finite supply, and scientists estimate their reserve will be depleted in as soon as 50 or as many as 120 years. Additionally, burning fossil fuels emits greenhouse gases into the environment, leading to pollution and climate change. According to the U.S. Environmental Protection Agency (EPA), the transportation sector emitted 1.745 million metric tons of carbon dioxide (CO₂) equivalent in the United States in 2011, or 28 percent of total greenhouse gas emission, an increase of 18 percent since 1990. This amount represents half of worldwide greenhouse gas emissions attributed to car travel. Greenhouse gas emissions in the atmosphere are reaching unsustainable levels, reaching 400 parts per million for the first time since CO₂ levels have been recorded, though scientists estimate this level has not been present in the atmosphere in millions of years.

Reducing the amount of emissions from the transportation sector is a global, urgent priority. This can be achieved through using alternative means of transportation such as walking or biking, engaging in fewer single-passenger trips through carpooling or public transportation, and increasing the fuel efficiency of traditional vehicles. Transitioning cars and other vehicles to green fuels offers one of the most popular strategies because the world population's enthusiasm for driving remains unabated. Several green, or alternative, fuels characterized by low greenhouse gas emissions are being used or developed; however, a number of barriers prevent acceptance and adoption of these innovations.

Biodiesel

Clean-burning and nontoxic, biodiesel, derived from new or used vegetable oils, animal fats, or recycled restaurant grease, comes in a number of grades: B100 (pure); B20 (a 20 percent biodiesel, 80 percent petroleum diesel blend); B5 (5 percent biodiesel, 95 percent petroleum diesel); and B2 (2 percent biodiesel, 98 percent petroleum diesel). The fuel is safe to handle, store, and transport and has been used in cars, trucks, boats, and even cruise ships. Biodiesel has lower emissions than traditional petroleum gasoline: B100 offers a 75 percent reduction while B20 reduces emissions by

15 percent. The EPA estimates particulate matter emissions decrease by 10 percent and unburned hydrocarbons by 21 percent. Biodiesel has similar performance characteristics as traditional diesel in terms of consumption, horsepower, and torque but offers a higher ignition value than diesel fuel. Some consumers worry that biodiesel will clog filters, but actually, it is a solvent. As such it can dislodge deposits from previous diesel fuel use, which can clog filters. Currently, the United States has 600 B20 fueling sites. As of 2004, 1,900 stations offered biodiesel in Germany for a total of 323,000 compared to 30 million tons of petroleum-based diesel. In addition to commercially available biodiesel, some individuals and cooperatives manufacture their own biodiesel fuel. Like that of ethanol, the production of diesel requires significant land outlays for the growth of crops. Most devastating might be the impact on tropical rain forests and their inhabitants, like orangutans, where the natural vegetation is wiped out for palm tree production.

Incorporating new crops such as algae into biodiesel production or utilizing waste oil offer an alternative to new growth for the fuel's raw material. An interesting and virtuous cycle has developed among biodiesel users and manufacturers around Victoria, British Columbia. Cruise Victoria Services, a sightseeing service that operates 19 buses, decided to fuel its fleet with B20 in 2007, gradually using B100 exclusively. As they increased demand, Cowichan Biodiesel Cooperative, which produces B100, needed to secure more vegetable oil for production. Instead of turning to new growth sources, they looked to the cruise ship industry and now utilize the waste of the ships that dock in Victoria. The system is local, closed loop, and good for the environment.

Electricity

Electric vehicles and plug-in hybrids operate through electric motors powered by rechargeable battery packs. Without a traditional engine, the electric vehicles have no greenhouse gas tailpipe emissions; however, the production of electricity does emit greenhouse gases unless the plant is powered by wind, solar, or water. Although the vehicles have lower fuel and maintenance costs, they are more expensive than traditional vehicles and have a limited range of 100 to 200 miles before recharging is needed. Mountainous terrain, the use of the car stereo or climate control, or climate can affect the range per charge. Each



Samples of different biofuels produced from algae are displayed at the BioProcess Algae facility at Green Plains Renewable Energy, Inc., in Shenandoah, Iowa, April 2011. Algae is currently being studied as a possible feedstock for biodiesel production and for the fermentation process for ethanol production. Algae is claimed to yield more fuel per unit area than other biofuel crops.

recharge can take up to eight hours if using a Level 1 charging station, four to five hours with a Level 2 station, or half an hour to charge the battery to 80 percent at a DC or quick-charge station. Currently, the United States boasts 5,800 public charging stations, and Pike Research estimates that more than 11 million recharging stations will be open worldwide by 2020. Without a well-developed recharging station infrastructure, electric vehicles have not become popular among mainstream consumers.

Ethanol

Once used by Henry Ford in the earliest Ford models offered for sale, ethanol (E85), a fuel made from sugar or corn, offers a biodegradable, renewable raw material as the basis of motor fuel. Many automobile companies have been manufacturing flex-fuel vehicles (FFVs), cars and trucks that can run on traditional gasoline or E85, for a number of years.

In the United States, over 7 million FFVs are on the road, but most of these are powered by petroleum-based fuel due to lack of consumer awareness and limited infrastructure, with E85 available at just over 2,400 stations in the country.

Sugarcane-based ethanol has been a popular fuel in Brazil, the second-largest producer of ethanol, for several decades, enjoying almost 50 percent of the gasoline market. Because ethanol contains less energy than traditional gasoline, vehicles require more E85 fuel to go the same distance as gasoline, and therefore drivers must fill the tank with more frequency. Vehicles powered by E85 can also have trouble starting on cold days. Otherwise, ethanol provides driving experiences similar to petroleum-based gasoline.

Ethanol has been criticized for using ingredients that might otherwise go into food and driving up demand and price for corn as well as for the

energy-intensive production it requires. To produce corn for ethanol requires significant acreage, which reduces wildlife habitat and biodiversity and impairs the earth's ability to absorb carbon dioxide. Furthermore, heavy amounts of pesticide are used to grow corn crops. Pesticides have been linked to groundwater pollution and wildlife deaths. However, governments and automobile manufacturers as well as other commercial researchers are investigating ways to make ethanol production safer and more efficient and are exploring the use of non-crop materials such as agricultural residue, including corn stalks, forestry residue including wood by-products, and substances such as algae, sorted municipal waste, and energy crops.

When manufactured from nonfood sources, the fuel is called "cellulosic ethanol" and has applications as fuel for passenger and fleet vehicles as well as for aviation fuel. In addition to seeking new raw material to create ethanol, researchers are aiding growers to discover ways to use fewer resources to produce the crops and helping manufacturers require less energy to convert raw materials into fuels. Ethanol costs and production, however, might be adversely affected by severe weather events, including droughts, which are more frequent with global warming.

Hydrogen

As explained by Joseph Romm, in simplest terms, a hydrogen fuel cell is a device that inputs hydrogen and oxygen and outputs water, energy, and gas. Hydrogen is pushed into a fuel cell stack where it is electrochemically converted to electricity, which powers a vehicle's motor. Because hydrogen fuel cells do not emit greenhouse gases, they represent an alluring option for green fuel. To be efficient in vehicles, however, fuel cells need to be small enough to fit under a vehicle's hood while powerful enough to provide the acceleration and performance drivers expect.

Consumers also expect engines to turn on with a turn of a key or push of a button, currently impossible with some fuel cells that operate at high temperatures and need time to ramp up. Additionally, fuel cells are expensive both because the technology is new and narrowly adopted and because of the energy intensity required to extract hydrogen from other particles, such as water or natural gas, which is a necessary step in using hydrogen in fuel cells. Furthermore, because hydrogen is a gas, it would

require a different delivery system and on-vehicle storage mechanisms. Current hydrogen tanks take up much more space than current gasoline tanks.

Despite the obstacles to hydrogen-fueled vehicles, many automobile companies, including Toyota and Volvo, are devoting research and development resources to practical and cost-effective fuel cell solutions. The Automotive Fuel Cell Cooperation, a joint venture of Ford and Daimler, conducts research with the goal to achieve commercial viability of fuel cells by 2015. Under certain conditions, the federal government provides tax incentives to consumers and companies who purchase hydrogen-fueled vehicles as well as to consumers and businesses who install hydrogen fueling equipment.

Natural Gas

The U.S. Department of Transportation (DOT) estimates that emissions from natural gas vehicles (NGV) are 6 to 11 percent less than from traditional gasoline, and depending on the type of natural gas, emissions across the life cycle can be decreased by as much as 29 percent according to the Center for Climate and Energy Solutions. Because natural gas fuel systems are sealed, the vehicles have no evaporative emissions. In the United States, most natural gas production is done domestically, so natural gas vehicles reduce the country's dependence on foreign oil. Cheaper than petroleum-based gasoline and sold in units of gasoline or diesel gallon equivalents, natural gas powers over 100,000 vehicles in the United States and approximately 11.2 million vehicles worldwide. Light, medium, and heavy-duty vehicles can be retrofitted to run on natural gas. Natural gas provides the same performance as petroleum-gas-fueled vehicles.

Natural gas fuel comes in several forms. Compressed natural gas (CNG) is stored in tanks at high pressure of 3,000 to 3,600 pounds per square inch. Liquefied natural gas (LNG) is stored in liquid form after the natural gas has been chilled to minus 259 degrees F. LNG must be kept cool or burned by engine so it is only suited for some vehicles, such as ships, trains, and long-haul trucks. Shell has invested in 100 LNG stations, and Clean Energy Fuels partnered with Chesapeake Energy Corporation and T. Boone Pickens to build 70 LNG stations to create "America's Natural Gas Highway." Renewable natural gas, or biomethane, is made from decaying organic material that is extracted from sites such as sewage

plants and landfills. Researchers are also working to convert algae into a source of biomethane. In Germany, Verbio has established 105 stations that sell natural gas fuel derived from agricultural waste.

Around the world, city and state bus fleets have purchased vehicles or converted existing vehicles to run on natural gas, including Dallas, Los Angeles, Phoenix, New York, San Francisco, Vilnius (Lithuania), Porto (Portugal), Brisbane (Australia), and the Mexican state of Jalisco. In the United States, catalyzed by the benefits of a natural gas fleet and enabled by a suite of federal and state grants, a number of school systems are moving to natural gas school bus fleets, including Los Angeles, Lower Merion (Philadelphia, Pennsylvania), Jordan (Utah), and Tulsa (Oklahoma). Commercial fleet vehicles around the world are also transitioning to natural gas vehicles, including General Electric, FedEx, Waste Management, AT&T, Hertz, and Tesco. UPS, which has just over 100 NGVs in its current fleet, has announced that it plans to increase that number to 800 by the end of 2014. Some companies, such as Procter & Gamble, Nike, and Walmart, pressure transportation companies to utilize NGVs to ship their goods.

While NGVs reduce emissions compared to traditional gas, propane provides less energy per gallon so vehicles require more frequent refueling. NGVs can be expensive, costing up to twice as much as conventional vehicles, and though fueling stations are increasing, they are not prevalent in the United States. The biggest disadvantage to NGV may be the hydrofracturing (fracking) process used to extract natural gas from shale mineral deposits. Although fracking has increased domestic energy production, critics note that the method requires significant amounts of water mixed with fracking chemicals. The disposal of the fracking waste water, exempt from the Clean Water Act due to a provision in the Energy Safety Act of 2005, may cause groundwater pollution and environmental damage. Since natural gas has myriad uses, the demand may increase the price of LNG and CNG, reducing its competitiveness as a fuel source.

Propane

According to the U.S. Department of Energy, 190,000 vehicles domestically and more than 14 million vehicles worldwide are powered by propane, which was first used in the 1940s to fuel vehicles.

Typically used in fleet vehicles such as school and shuttle buses, taxis, and light trucks, propane can be a viable alternative for fuel because of its effective performance, strong safety record, clean-burning qualities, and availability within the United States.

Propane-powered vehicles exhibit the same performance as gasoline engines but have greater engine efficiency and smoother engine running. Analysis using the GREET model for life cycle petroleum use and greenhouse gas emissions indicated that propane emissions were 10 percent less than petroleum-based oil, but when derived as a natural gas production by-product, emissions could be 98 percent less.

In liquid state, propane has a low flammability range and is nontoxic, nonpoisonous, and insoluble in water, but if leaked it becomes a gas and can ignite. While propane and petroleum-based gasoline have similar costs, propane produces less energy per gallon than gas, and vehicles require more frequent refueling. Propane, which is stored in tanks, typically above ground, can be offered at the same stations as traditional and diesel fuel and is dispensed very similarly to those fuels.

Vegetable Oil

Although the practice is illegal in the United States due to EPA guidelines, diesel cars and trucks can be converted to run on straight vegetable oil (SVO). Drivers can purchase refined vegetable oil or find a source of used vegetable oil from restaurants, though used vegetable oil must be filtered to remove food particles. Vegetable oil is more viscous, or thicker, than diesel oil so the conversion kits in part heat the oil to allow it to pass through the engine. SVO—renewable, nontoxic, and biodegradable—can be placed in compost piles if spilled. Because SVO is not a commercially available fuel, few studies have been conducted to examine the emissions of vehicles using SVO. Most available data suggest that emissions are significantly lower than when using petroleum-based diesel. Additionally, soot emissions are reportedly as much as 60 percent lower than with traditional diesel-burning engines.

Barriers to Adoption

David Banister has delineated several common barriers preventing the use of sustainable transportation methods, which researchers have also

applied to alternative or green fuel. First, financial barriers, or increased costs for manufacturers and consumers, reduce the likelihood of green fuel acceptance and use. Governments and private donors may subsidize research or infrastructure development. In the United States and the United Kingdom, national governments provide tax incentives and grants to individuals and some commercial fleets who purchase vehicles powered by green fuels. Even with incentives, consumers may have difficulty calculating the long-term benefits of green-fueled vehicles versus the short-term immediate costs of the vehicle if the vehicle demands a premium price, as electric vehicles do.

Technological barriers include machines and processes to manufacture green fuels, as well as concerns about the availability of raw material or structural barriers related to the infrastructure, including the retail availability of green fuels, which can dissuade companies from investing in green fuel vehicle research and development and consumers from purchasing what vehicles are on the market. Institutional barriers include the predominance of fossil fuels in the transportation industry, which breeds commitment to the status quo and fear of change among stakeholders.

The preceding three barriers impact the fourth, public acceptability, which requires that consumers favorably evaluate the fuels in terms of availability, impact, safety, and cost. With new technologies, regulatory or legal barriers can inhibit development, such as competing standards for plugs and receptacles in electric vehicles and charging stations or fear of legal challenges.

A fifth barrier, policy failures or unintended impacts, can diminish support of green fuels, as when media reported spikes in corn prices making the material cost prohibitive in some regions due to demand for corn to manufacture ethanol. Physical barriers represent the final impediment to green fuel adoption, such as limits to raw material. Equally applicable to all types of green and alternative fuels, these barriers must be tackled by governments, interested nonprofit organizations, and manufacturers if the world's drivers are to successfully transition from a fossil-fuel based transportation system.

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See Also: Alternative Fuels; Biodiesel; Biofuels; Electric Vehicle Recharging Stations; Environmental Protection Agency; Ethanol; Hybrid Automobiles/Hybrid Electric Vehicles; Hydrogen Fuel; Hydrogen Fuel Cells.

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Green Transportation

Green transportation is a concept that relates ecological and aesthetic concerns to transportation. Green transportation is associated with efforts to minimize carbon footprints and is often linked to a transportation infrastructure supporting a green milieu or more resilient cities. This concept also relates to energy systems as well as questions of urban planning and urban form (including architecture). Examples of green transportation modes include walking,

cycling, alternative-fueled vehicles, and mass transportation. Transportation is responsible for about 13 percent of global greenhouse gas (GHG) emissions and 26 percent of global CO₂ emissions. Cities consume 75 percent of the world's energy and emit 80 percent of the world's greenhouse gases. Therefore, redesign of transportation systems and cities is essential for achieving ecological objectives. Peak oil and climate change are seen as key drivers for greener cities and transportation modes. A transportation system can also affect air quality, noise, water quality, soil quality, biodiversity, and land utilization, such as transit infrastructure.

There are different ways to define green transportation. First, one can analyze the emergence of a discourse that helped define what "green" or "ecological" outcomes are. Second, one can examine the history and impacts of various technologies and explore whether they have a greater or lesser carbon footprint, are more energy efficient, or can adapt themselves to a renewable or sustainable system. Third, one can look at the land use impacts of different transportation technologies and associated infrastructure in terms of their ability to limit congestion, promote concentration, or affect aesthetic outcomes. In sum, to understand what constitutes green transportation, one must apply multiple criteria.

There are advantages and disadvantages to various green transportation modes, depending on the criterion one applies. Something may be called "green" but may only be ecological in relative rather than absolute terms. The ensemble of how different green transportation modes fit together with an ecological infrastructure could be said to constitute a "green transportation" system, with such an infrastructure working better in some cities than others.

What Is Green?

An early source of environmentalism was the idea of conservation, which placed an emphasis on preserving nature and with human beings having special responsibility for such preservation. Robert J. Brulle notes that "conservation had a resurgence under the label of Sustainable Development" in the mid-1980s. Sustainability, however, involves "many different definitions, none of which has achieved ascendancy." One key question is the extent to which governments and corporations embrace the concept and the consequences of their doing so.

In the context of green transportation, the debate centers on the ecological impacts of some modes of transportation or fuels supporting such transportation, with criticism directed particularly at ethanol-based cars or the use of alternative-fueled cars rather than mass transportation.

Barry Commoner explained a basic green principle concerning the relationship between two realms: "the natural ecosphere, the thin global skin of air, water, and soil and the planets and animals that live in it," and the human-made "technosphere." The technosphere "has become sufficiently large and intense to alter the natural processes that govern the ecosphere." The result of a clash between these two spheres has resulted in flooded cities, droughts, contamination of water and food, poisoning of bodies, and a diminished capability to provide for human needs.

Thinkers like Commoner, Seymour Melman, and Paul and Percival Goodman saw a way out of this contradiction, partly through alternative energy, alternatives to the internal combustion engine, and alternative ways to design cities. Through direct or indirect means, these kinds of interventions could lower carbon emissions. Technology and alternative plans can play an important role in solutions, with Peter Newman and colleagues arguing that "the ability to experiment and innovate" is "the tissue of hope and the core of resilience." The buildup of atmospheric greenhouse gases from land use changes and continued combustion of fossil fuels over the past century threatens to promote catastrophic changes if certain remedial thresholds are not met. Thus the ultimate criterion for what is "green" could be the combined policies and practices that put us on a transportation path that avoids the worst ecological outcomes. As of 2012, one internationally accepted estimate was that the planet should not increase more than 2 degrees C, with leading U.S. climatologist James Hansen arguing that even this threshold is far too high and that the latitude society has to emit more greenhouse gases is decreasing significantly by the day.

The Energy Dimension

In some cities, green interventions have been linked. For example, Bilbao, Spain, was the first city to use only renewable energy sources to power its subway system. Jon Rynn explains that with electrified vehicles on transit systems, "motors are located right

next to the wheels,” whereas in “an internal combustion system, the motor has to transmit [to] the drive shaft, that is, a rigid piece of steel that is turned by the power of the engine, and that in turn turns the wheels.” Electricity creates a more efficient system because it allows you “to take the power source off the vehicle,” in contrast to cars and trucks, which must carry the power sources in the vehicle.” Most important is the ability of electricity to act as a conduit between various kinds of green vehicles on the one hand (high-speed rail, heavy rail, light rail, electric buses) and cleaner or renewable energy sources on the other (wind, solar, hydroelectric power). Despite the potential advantages of electric power, there can be thermal losses when converting fuels to electricity. Even if electricity is generated by wind or solar power, there can be losses associated with moving that power to points of use. The U.S. Energy Information Administration found that “national, annual electricity transmission and distribution losses average about 7 percent of the electricity that is transmitted in the United States.”

The ability of an energy system to be green requires that it follow the principles of sustainable development. Herman E. Daly lists two key principles regarding renewable resources: “First that harvest rates should equal regeneration rates (sustained yield). Second, that waste emission rates should equal the natural assimilative capacities of the ecosystems into which the wastes are emitted.” The basic idea is that the best energy systems can be replenished with minimal waste and that the use of an energy source should not surpass the capacities of the ecosystem. For example, wind energy is renewable (replenishable). The wind turbine by weight is mostly composed of recyclable metal, with much of the rest coming directly or indirectly from fiberglass, sand, and plastic. Plastics can be recycled and can come from sustainably harvested biomass. The linkage of electric-powered cars and trains to such clean energy sources therefore has ecological advantages.

Automobiles and Alternative Fuels

Automobiles are the second-largest contributor to greenhouse emissions in the transport sector. Stephen Potter shows that 76 percent of CO₂ emissions from an average car come from fuel usage, 15 percent from emissions and losses in the system used to supply fuel, and 9 percent from manufacturing

the vehicle. The internal combustion engine dominates auto propulsion systems. There are different ways to advance green transportation alternatives, including increasing fuel efficiency, the use of alternative fuels, car sharing, and attempts to reduce automobile usage. Driverless cars might contribute to reducing fatalities and congestion (by coordinating spacing), providing some limited ecological benefits. In August 2012, the Barack Obama administration issued rules that would require automakers to almost double the average fuel economy of new cars and trucks by 2025. Fuel efficiencies can be lost to increased driving made possible by the fact that such efficiencies are equivalent to decreases in fuel costs. In contrast, fuel taxes would more unambiguously reduce fuel use. The Central London Congestion Charging initiative considerably reduced traffic into the inner city. A comparison of the pre-congestion charging (2000–02) and postcongestion charging periods (2003–07) shows increased business activity in the central charging zone and decreased performance in outer Inner London and Outer London.

Alternative fuels include (1) electricity, which as noted can be a vehicle power source, but Jean-Paul Rodrigue notes that “The low energy capacity of batteries makes the electric car less competitive than internal combustion engines using gasoline,” although the technology is improving. Such improvements would lower infrastructure costs or logistical barriers for light rail systems and could promote electric fleet vehicle use. (2) Biogas fuels (such as ethanol, methanol, and biodiesel) come from wood waste or fermentation of food crops. Production of such fuels may compete with other uses of land. Yet, *Jatropha* uses marginal land in contrast to sugarcane. (3) Hydrogen uses fuel cells to generate electricity to propel a motor vehicle, though much energy can be wasted by its storage, production and transfer. Hybrid electric vehicles link an internal combustion engine and a supplemental electric motor with a battery power source.

The private automobile continues to gain market share at the expense of public transit systems in North America, in much of Europe, and in most developing countries. Moreover, Maja Essebo and Guy Baeten discuss the following:

Tataism—shorthand for the generalisation of motorised transport and production in new

Asian growth centres . . . may dwarf the first car era and may truly globalise a socio-spatial form centred on the private motorised car.

Tataism is named after the “Tata Nano,” the world’s least expensive car. Despite increases in fuel efficiency or even the use of alternative fuels, Tataism considerably reduces many advantages coming from such green transportation approaches. Automobiles and trucks use far more land per person than alternative transportation modes.

Walking and Bicycles

Walking and bicycling’s share in the total number of trips is significant almost everywhere. Their many advantages include favorable environmental performance, the provision of door-to-door transport, their high spatial penetration, the absence of waiting times compared to public transport, their status as inexpensive transport modes, their importance to multimodal transport chains, and their contributions to human health. Potential disadvantages of these modes include their low speed (which is relative to the level of congestion of other modes or even the layout of transit routes), relatively high accident rates, low level of comfort (susceptibility to weather conditions), and physical effort required (depending on factors such as gradients, temperature and wind, although such efforts can have health advantages).

While walking is the most important form of transportation, its fuel comes from agriculture, which is seldom “clean” and often energy intensive. A green alternative would include locally grown crops using less energy to cultivate them. Rynn notes that before the advent of trains, “cities were basically only as big as could be walked in a reasonable amount of time.” While “trains allowed the first suburbs to form,” suburbs still needed to have “houses within walking distance of the rail station.” Increases in income levels, urban sprawl, and low-density construction have usually acted as barriers to nonmotorized transport modes. Nevertheless, there has been a renaissance in bicycle use in a number of European countries like Denmark, Sweden, Germany, and the Netherlands. In the United States, the bike mode share rose more than 500 percent in Portland, Oregon, between 1990 and 2009, and doubled in New York City during the same time span. The U.S. Rails-to-Trails Conservancy found that the total savings resulting from “shifting more

short trips to bicycling or walking” could range from 2.4 to 5 billion gallons of fuel, or “between 21 and 45 million tons of CO₂ a year.”

Public Transit

The collective forms of passenger-carrying transportation services go by various names, including “transit,” “public transport,” and “public transit.” Public transit includes paratransit (including vans, jitneys, shuttles, minibuses, and minibuses), bus transit (or “coaches” in the UK), trams and light rail transit, heavy rail and metros, and commuter and suburban railways. Studies cited by Potter show that a medium-sized car releases 78 grams of CO₂ per seat-kilometer, in contrast to 26 grams for a double-deck bus, 33 for a single-deck bus, 38 for light rail, 39 for an urban electric train, 40 for a minibus, 46 for a metro/underground, and 60 for an urban diesel



A bicycle parking facility at a train station in Uppsala, Sweden, in 2007. The bicycle mode share (percentage of commuters biking to work) is increasing in some U.S. cities such as Portland, Oregon, which saw an increase of over 500 percent from 1990 to 2009.

train. Studies cited by Lee Chapman found that a gasoline (petrol) car with two occupants emitted more than twice as much CO₂ emissions (grams per kilometer per occupant) as a conventional train and four times as much as a coach. Trains can do better, depending on their fuel source.

Despite its ecological advantages, the use of public transit significantly differs, depending on the country and region. Ralph Buehler and John Pucher found that the number of annual public trips per capita in Europe and North America (2005–10) was 237 in Switzerland, 139 in both Sweden and Germany, 116 in Great Britain, 87 in France, 69 in Denmark, 65 in Italy, and 51 in the Netherlands, but only 24 in the United States (with bike transit significant in both Denmark and the Netherlands). From 2009 to 2010, the share of American workers commuting by public transit was only about 5 percent, which was one-third as high as the German share. Within Germany itself, however, the share of all trips by public transit (2003–07) was 10 percent in both Muenster and Aachen, 21 percent in Frankfurt/Main, and 27 percent in Berlin.

Other Modes: Road Freight, Aviation

Road freight is the largest contributor to greenhouse gas emissions in the transport sector. Studies by the World Business Council for Sustainability have shown that freight movement uses about 43 percent of all transportation energy, and that slow-moving vehicles cause significant highway congestion. Benefits from “dematerialization” (product miniaturization, use of lighter materials, increased product durability, service sector growth) have not reversed the increase in total material consumption tied to global growth. Fuel efficiency in freight has increased and trucks can adapt to bulkier fuels like heavy fuel cells and hydrogen, but globalization has increased freight demand and transport distances. Green policies include making manufacturers more responsible for the ecological impacts of the entire life cycle of their products, the development of regional production clusters to reduce transportation costs, and use of taxation to encourage more efficient trucks or shifts to more sustainable shipping patterns. Studies have found that, generally speaking, “intermodal transport” is far more ecological than road or unimodal transport.

Aviation has produced vast quantities of global climate-changing pollutants. Chapman explains

that “aviation is now an essential part of the world economic system,” with the increased use of aircraft leading not only to landing delays that reduce fuel efficiency but also to “increased gas emissions and ultimate, an institutional failure leading to an unsustainable programme of airport expansion.” Among the reasons for such increases are “cheaper and more abundant flights.” Tourism, often tied to air travel, is a key factor tied to growth and air pollution. Green alternatives include solar-powered planes (which are now in their infancy), and substitution for aircraft by high-speed rail (HSR). HSR has cut into air modal shares in France, Japan, Spain, and the Republic of Korea.

Infrastructure, Planning, and Urban Form

Government deregulation has increased fares for mass transit, just as rising personal incomes and car ownership, decentralization of cities and regions, and periodic declines in motoring and parking have reduced mass transit usage. A kind of vicious cycle has linked spatial decentralization and use of motorized transit: more spread-out development encourages car and truck use, and vice versa. The relatively speedy and flexible door-to-door transportation system of automobiles has usually put mass transit systems at a disadvantage when trip origins and destinations are spread all over the map. In the United States, federal policies to encourage automobile and highway use, together with the existence of cheap oil, have compounded the problem of decentralization.

There are, however, barriers to this decentralized spatial pattern and associated motor usage. First, traffic congestion has slowed speed, efficiency, and fuel economy. The existing transportation infrastructure in many countries is unable to cope with further increases in the number of motor vehicles, creating congestion problems in many towns and cities around the world. Congestion reduces the time available for alternative activities, potentially making cities with severe problems less competitive.

Second, historical and physical factors can retard an urban sprawl pattern. Land scarcity may make it too costly to spread development out, with island cities and states like New York City and Singapore unable to adapt without a dense pattern. Cities like New York, built before the car era, were unable to provide many parking lots or widen their streets to accommodate the automobile.

Third, some locales have supported denser, more sustainable patterns because of the desire to preserve open space, support ecological goals, and historical preservation interests or other aesthetic values. Mark Luccarelli explains that in the United States, the diffused metropolis produced “a sprawling, visually blighted, and functionally differentiated amalgam of existing towns and cities, residential subdivisions, industrial and office ‘parks,’ shopping centers, and malls.” Growth not only comes at the expense of the surrounding countryside but also has deprived the urban core of its integrity and its amenities.

Finally, cities that offer cultural amenities, density, mass transit access, and certain aesthetic values have certain market advantages, particularly as cities compete with one another for members of a professional-managerial class, many of whom increasingly want to live in less automobile-dependent cities. Cities with amenities like bicycle paths, light rail, accessibility by walking, and the reduced need for a car will often be more competitive in attracting such professionals. Alan Ehrenhalt concludes that deindustrialization and reduced crime have produced cleaner, safer cities in the United States, leading to a process where more affluent persons stay or move into the inner cities, and the poorer can be pushed out to the suburbs. He says professionals are attracted to the city, some wanting the following:

Jane Jacobs’s 1950s version of Hudson Street in New York’s Greenwich Village, with locally owned and slightly messy bookstores, coffee-houses, and bars, and a concentration of art galleries and studios.

Some emerging trends suggest hope for urban forms that lend themselves to greener transportation modes. Ecological thinkers like Lester Brown cite “a declining interest in cars among young people,” which some link to socialization processes linked to communication technologies like smartphones and computers, a preference for urban living, or the financial squeeze facing college graduates. Parking fees have also begun to rise in many cities. A 2012 survey of 44 central business districts in the United States found only 13 percent had abundant parking availability and just six expected the construction of new parking in the next two years. Many older

persons are not able or willing to drive, so here too is an important mass transit market.

Congestion problems, the need for efficiency, and reduction of energy use/ecological impacts have led to the advocacy of greater urban density as a necessary element of any green transportation system. Greater density facilitates the use of mass transit options; walking and cycling are the greenest (most ecological) modes of transportation. Mayors in the United States, concerned about air pollution and congestion, have waged a fight to reduce automobile usage. A review by Brown found that “almost every U.S. city is either introducing new light rail lines, new subway lines, or express bus lines, or they are expanding and improving existing public transit systems in order to reduce dependence on cars.”

David Banister cites empirical research, concluding on key parameters of a sustainable city:

The key parameters of the sustainable city are that it should be over 25,000 population (preferably over 50,000), with medium densities (over 40 persons per hectare), with mixed-use developments, and with preference given to development in public transport-accessible corridors and near to highly public transport-accessible interchanges.

Density supports the needs of information sharing, and various service sectors require face-to-face exchanges or the creation of a certain milieu or localized community culture.

Policy Questions

Despite these trends, Chapman argues that aviation and motor cars are “increasingly the favored modes for passenger transport, but are also significantly the most damaging” for the environment. Such “favored modes need to be made less polluting through technological change or alternative modes need to be made more attractive via behavioral change driven by policy.” In the United States, trend data shows a strong preference for traditional cars, with fuel prices not drastically reducing car use. The small car share of the market is no longer driven heavily by real fuel prices. As cars get smaller and more efficient (even where fuel prices are higher due to taxes), it would take much higher taxes to obviate the economic advantages of better fuel economy.

The constraints on technological solutions come from the “Jevons paradox,” in which the greater efficiency of an energy system can lead to its greater use. One view is that without stiff fuel taxes in North America and China, the expansion of mass transit will not be able to reverse the tide of global warming because oil prices are currently stable-to-falling. Conversely, the taxation of fuel and vehicle miles traveled would push citizens toward denser living and reduce the number of vehicles per household. Citizens with reduced living standards and unable to afford a car could contribute to a growing mass transit lobby.

Among the policies that have encouraged green transport cities or a shift to public transport are expanding and improving public transport service; integrated and attractive transit fares; regional and intermodal coordination; pricing and restrictions on car ownership, use, and parking; and land use policies that encourage dense and mixed-use settlements. New budget priorities at the national level are of central importance; one way to get them might be through corporatist coalitions linking the government, transit manufacturers, labor unions, and social movements.

A comprehensive understanding of green transportation necessitates that one examine potential trade-offs. There are pragmatic or policy-oriented views about the short-term benefits of a given technology and infrastructure. There are also more “utopian” visions for what an ideal community looks like, such that green transportation facilitates the achievement of multiple goals (be they related to ecology, economy, energy use, mobility, or aesthetics). For example, the technology used in an electric-powered train is more or less green, but if the energy source for the train is coal or petroleum, the technology itself ends up not being very green.

Conversely, one could have a very green-powered light rail system that promotes exurban, low-density growth, and sprawl. Such a system might be green in terms of its own environmental impacts but encourage a spatial decentralization that is not more energy efficient. On the other hand, a light rail system that decreases car use might still be considered relatively green. Some suburbanization can be considered green if it breaks down the divide between “town” and “country” (urban life and rural life) and can create a green aesthetic that is valuable

on its own account, for example, “garden cities” that are small scale, pedestrian friendly, and still on the outskirts of the inner city.

Given these various trade-offs, a consideration of the utopian green transportation community that meets multiple goals is useful. So too is the study of different cities and technologies and how these fit together. Various models for green cities supporting green transportation have been compiled by the World Wildlife Fund and Timothy Beatley in *Green Urbanism*.

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See Also: Alternative Fuels; Environmental Impacts; Environmental Justice; Green Fuels; Light Rail Transit; Sustainable Transportation; Transit-Oriented Development.

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Greenhouse Gases

Greenhouse gases (GHGs) are chemical compounds in the Earth's atmosphere that trap heat by absorbing infrared radiation from the sun. Gases include water vapor, carbon dioxide, methane, and nitrous oxide and can be produced by natural systems as well as human activity. Carbon dioxide is of particular concern because it is the most abundant GHG and its level has been steadily increasing since the Industrial Revolution began around 150 years ago. The level of carbon dioxide increases when the amount of the gas produced exceeds the Earth's ability to absorb (or sequester) carbon through natural processes such as plant photosynthesis.

The Keeling curve, named after scientist Charles D. Keeling who pioneered the study of atmospheric

carbon dioxide, shows how the level has increased since 1958. For earlier periods, scientists have obtained information about the amount of carbon dioxide in the atmosphere by examining ice cores. The data show that before the Industrial Revolution, the level of carbon dioxide was around 280 parts per million (ppm) and increased steadily between 1850 and 1950 to around 320 ppm. Since then, the rate of increase has been much more rapid, and the level is now in excess of 400 ppm.

Relationship to Global Climate Change

Rising concentrations of GHGs cause concern because they increase the average temperature of the earth, which sets off a chain reaction that affects climate patterns in complicated and difficult-to-predict ways. Because carbon dioxide is the most important GHG, the amount of energy used by an entity has been termed its "carbon footprint."

Transportation is an important part of any discussion about GHGs and carbon footprints because it accounts for such a large share of carbon dioxide emissions (28 percent in the United States, 24 percent in Europe, and 13 percent globally), and it has been the fastest growing component over the last several years (increasing 20 percent between 1990 and 2001 for a group of 31 European countries).

The complex ways in which people affect climate has been the subject of growing and often vigorous debate for several decades. Some have been skeptical that people's actions can affect climate at the global scale and have instead attributed changes in climate patterns to natural variations rather than a more fundamental shift caused by human activity. Two specific aspects of the scientific process that have been challenging for policy makers and the general public to reconcile are the fact that all scientific studies have some statistical uncertainty associated with them and that different studies or climate models suggest various outcomes.

In contrast to those who have been skeptical about human-induced climate change, other entities have responded to the threats associated with rising GHG emission in a more proactive manner. The United Nations Framework Convention on Climate Change (UNFCCC) is an environmental treaty with the stated goal of preventing dangerous human-induced interference of the climate system. In 1997, most countries in the world signed the

UNFCCC's Kyoto Protocol, which contained binding obligations to reduce emissions of GHGs.

Although the United States and Canada have yet to ratify the Kyoto Protocol, other agreements and legislation that they have enacted do reflect growing concern about GHG emissions in general, carbon dioxide in particular, and acknowledge the pivotal role played by transportation. For example, in 2009, the U.S. Environmental Protection Agency (EPA) ruled that the current and projected levels of carbon dioxide and five other GHGs constitute a threat to public health and the welfare of current and future generations. What is noteworthy about this decision is that the EPA specifically mentioned GHG emissions from motor vehicles—mobile sources of pollution—in contrast to previous pollution regulations that had focused mainly on point sources of pollution such as factories and power plants.

In addition to national-scale initiatives, governments at a wide variety of other scales have recognized the need for legislation to address global climate. Various networks of local governments and city mayors have emerged over the past few years to share information about and promote initiatives focused on various aspects of sustainability. One prominent example of such a network is ICLEI, which originally stood for the International Council for Local Environmental Initiatives, but in 2003 the organization changed its name to become ICLEI Local Governments for Sustainability. Members of this network span the globe and comprise more than 10 megacities, 100 supercities and urban regions, and 450 small and medium-sized cities, located in more than 80 countries. While initiatives pursued by ICLEI Local Governments for Sustainability are quite broad-ranging, transportation is a pivotal factor in the move toward either low-carbon or carbon-neutral settlements.

Carbon Footprint

The concept of a carbon footprint reflects concern about GHG emissions in general and carbon dioxide levels in particular. The term *carbon footprint* is related to the concept of the ecological footprint put forward by William Rees and Mathis Wackernagel in the 1990s, which estimates the number of “earths” that would theoretically be required if everyone on the planet consumed resources at the same level as the person calculating their ecological footprint. Carbon footprints are much more specific

than ecological footprints because they measure direct emissions of gases that cause climate change in the atmosphere. The motivation behind being able to calculate carbon footprints is to quantify and reduce environmental impacts, which can be achieved either by reducing the amount of carbon dioxide produced or by increasing the amount of carbon dioxide absorbed by nature through initiatives such as planting trees. This quantification of carbon footprints has also led to increased discussion of carbon taxes and of a process known as “cap and trade” whereby entities can meet their obligations with respect to carbon footprints by making improvements in other areas.

Transportation-Related GHG Emissions

Transportation GHG emissions are the outcome of four factors: (1) vehicle fuel efficiency, (2) the carbon content of the fuel used, (3) the number of miles traveled, and (4) the operational efficiency achieved during travel. Reducing transportation-related GHG emissions could therefore be achieved by improving one or more of these parameters. While that may sound straightforward, the issue is not that simple. First of all, countries around the world are experiencing different dynamics in the underlying structure of their economies and hence different outlooks for the trajectory of GHG emissions. In developed countries, per capita GHG emissions are already high, with the United States having the largest overall and transportation-related GHG emissions in the world. In developing countries, although per capita GHG emissions are low compared to developed countries, industrial activity and population are growing more quickly, leading to faster increases in the rate of growth of GHG emissions. While each country has its own carbon trajectory, briefly examining China and the United States illustrates some of the differences facing developing and developed economies as they seek to lower their carbon footprints.

In 2006, China overtook the United States as the world's largest GHG emitter, and according to the Energy Information Authority, China's carbon dioxide emissions rose by 170 percent between 2000 and 2012. Much of China's GHG emissions come from its high reliance on coal, which supplies nearly 70 percent of China's primary energy, more than twice the world average. China has recently pledged to transition toward a low-carbon economy by 2020,

increasing its nonfossil-fuel consumption to 15 percent of primary energy consumption, and increasing the amount of forests to absorb carbon dioxide. Policies to help reach these goals include a carbon tax and national emissions trading scheme that is expected to begin in 2016. Transportation currently accounts for only 6 percent of China's total GHG emissions, but vehicle miles traveled are expected to increase rapidly with higher per capita incomes. While it is difficult to predict whether increased household income in China will translate into the same rates of growth in vehicle ownership that have occurred in other places, some researchers predict that China could have as many vehicles in total as the United States by as early as 2030. Given the implications of such a transition for global carbon dioxide emissions, many around the globe are interested in China's plans to manage its transportation-related carbon footprint.

China launched an ambitious high-speed rail service in 2007, and as of 2012 has the busiest high-speed rail network in the world with daily ridership in excess of 1.33 million passengers. By the time the system is completed (which is estimated to take place in 2020), China will have the largest, fastest, and most technologically advanced high-speed rail network in the world. In addition to these transportation innovations, China is also experimenting with building eco-cities. The country has a tremendous amount of scope to be forward-looking in how it manages its settlement patterns to accommodate its growing population. Given that most of the transportation infrastructure has yet to be built, there is also a considerable amount of scope to shape the extent to which that infrastructure will promote low-carbon energy use. For example, national policies could prioritize the adoption of alternative fuel vehicles and create a physical infrastructure to support that option by providing alternative-energy refueling stations.

Transportation in the United States contributes approximately 28 percent of the country's total GHG emissions, and emissions relating to transportation have grown faster than those of other sectors. Between 1990 and 2006, growth in U.S. transportation GHG emissions accounted for 47 percent of the increase in total GHGs in the nation. It is widely believed that implementing strategies that reduce transportation-related GHG emissions is critical to reaching national goals. As mentioned

above, reducing transportation-related GHG emissions requires exercising one or more of the following four options: (1) improving vehicle fuel efficiency, (2) decreasing the carbon content of the fuel being used, (3) reducing the number of miles traveled, and (4) improving the operational efficiency achieved during travel. Stakeholders have experienced difficulty agreeing on which path to take toward a lower carbon future.

Policies in Developed Countries

Part of the problem in reaching consensus is that some approaches require policies that change behavior (such as reducing the number of miles being driven) while others rely upon technological fixes to the problem (such as improving vehicle fuel efficiency). People's faith in the ability of technology to provide a solution to environmental problems is a fundamental reflection of their environmental values, and these vary across a wide range of dimensions including age, income, education, gender, race/ethnicity, and political affiliation. Further complicating the issue is the fact that sometimes people are prevented from undertaking behavior that reflects their environmental values because of what environmental psychologists have referred to as "social traps." One prominent example that is quite common in the United States is that people may prefer to use public transportation rather than personal vehicles but are prevented from doing so because the physical infrastructure is not available. That said, a raft of public policies inspired by smart growth, sustainable development, and sustainability goals have been enacted in the United States over the past 20 years or so.

Many land use and transportation policies adopted in developed countries across the world, but most prominently in the United States, in the past decade or so have been directed at countering urban sprawl. While difficult to define, this phenomenon is generally associated with low-density, automobile-oriented patterns of development. The extensive research on sprawl has uncovered many ills, such as the loss of agricultural land and species habitat and increased pollution from tailpipe emissions. Perhaps one of the most unpalatable outcomes of sprawl has been that Americans are having to travel more in order to access the same goods and services as they did previously, incurring what Chuck Kooshian and Steve Winkelman

have referred to as “empty miles” in the Urban Land Institute publication *Moving Cooler*. People have begun to realize that continuing to decentralize activity in this manner is creating a vicious cycle between land use and transportation that has negative implications for carbon footprints (as well as household spending on transportation). Support is growing for alternative patterns of development. Clustering housing and other activities onto the spine of transit to reduce the amount of travel that people undertake is a common theme among sustainability-oriented approaches to urban planning.

Another factor that complicates the transportation policy landscape in the United States relates to a concept known as “path dependence,” which refers to the fact that the country has already invested in an expansive transportation network consisting primarily of interstate highways. There is one car for every 1.3 people in the United States, of which only about 4 percent are alternative-energy vehicles. As a result, the technology for alternative-fuel vehicles is more advanced than the infrastructure to support it. Reducing emissions by switching to alternative-fuel vehicles is therefore limited by the extent to which financing can be obtained to build refueling stations to support a fleet that does not rely on gasoline.

Consequently, a considerable amount of faith is being placed on the extent to which the world can respond to what some people have begun to call the upcoming “carbon emergency” by improving vehicle fuel efficiency. Places experience tremendous variations in the size, age, and type of vehicles that people drive—known generally as the fleet composition—that affects the average fuel efficiency of vehicles. In Japan and many European countries people tend to drive smaller and more fuel-efficient vehicles. In contrast, until very recently, the trend across much of the United States tended to favor larger, heavier, and less fuel-efficient sport utility vehicles (SUVs) and minivans and trucks (especially in more rural areas).

Differences in fleet composition result in variations in the capacity for reductions in GHG emissions from place to place. The most scope for improvement in vehicle fuel efficiency exists in the United States, which has consistently lagged behind other countries in fuel efficiency, despite the adoption of increasingly stringent Corporate Average Fuel Economy (CAFE) standards over the years.

The International Council on Clean Transportation conducted an extensive review of major transportation policies announced since 2000 to determine the effect that they would have on global GHG levels and published its findings in a report in 2012. It concluded that spreading the world’s most advanced regulatory standards and cost-effective technologies to other major markets while supporting shifts to low-carbon modes could stabilize global transportation emissions by 2020. However, it added that despite the large magnitude of emission reductions that can be achieved from the adoption and implementation of transportation policies, these policies will not put the transportation sector on a path to reduce emissions (from 2000 levels) by 50 to 85 percent by 2050, which is the extent of economy-wide emission reductions agreed upon by governments worldwide in order to limit the increase in global temperatures to 2 degrees Celsius. Instead, it warned that achieving such reductions in the transportation sector would need to rely on a wider range of policies enacted in parallel with technological innovations in transportation.

Of particular note is their view that gains made by improving vehicle fuel efficiency will be offset by the expansion of vehicle fleets and activity in developing countries. This view underscores the limitations of relying on one particular strategy to achieve GHG emission reductions and supports the idea of a multipronged approach that includes all of the possible options available to reduce transportation-related carbon footprints.

To summarize, many stakeholders around the world recognize the need to transition to a low-carbon economy and acknowledge that transportation policies are an integral part of this decision process. That said, transportation policies cannot be enacted in isolation from other decisions that affect human settlement patterns, such as where to locate housing, jobs, and the wide array of other activities that people need to access. It is becoming increasingly evident that if global climate change is to be limited to the 2 degrees Celsius stipulated in the Copenhagen Agreement, transportation policy will need to be conceptualized with a much broader geographic scope in mind than the immediate population that any individual system may serve.

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See Also: Air Pollution/Air Quality; Clean Air Act and Amendments; Climate Change, Transportation Adaption to; Green Fuels; Transportation Impacts on Land Use; Vehicle Emissions Standards.

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Greenways

Efforts to mitigate the impact of urbanization on people and the environment have given rise to the growth of the greenway movement. A greenway is generally a strip of open land of varying widths, including land along natural features, land reclaimed from an industrial or other use, or otherwise vacant land. Greenways usually connect communities, neighborhoods, parks, recreation areas, or other greenways. Nonmotorized transportation is encouraged in these spaces, although motorized transportation is often accommodated. Greenways provide for movement of people, animals, water, and even seeds and can be found in urban, suburban, and rural environments. Greenways found outside urban areas may stretch for many miles and may be very wide.

The development of greenways is a reaction to the rapid urbanization of the world. As cities

become larger and as the populations of cities live closer and closer to other residents, there is a desire for green space. The environmental movement led to a call for less dependence on carbon-emitting transportation. Walking and cycling have been promoted as ways to reduce pollution while benefiting the health of those who take part in these activities.

These linear strips of land provide environmentally friendly transportation corridors. Often attempts are made to form a network of greenways, thereby multiplying their usefulness by giving access to other areas. A greenway may incorporate some of the built environment of the city.

Greenways are also seen as ways to protect the environment through the nature of their settings, as with a greenway running along the floodplain adjacent to a river. Greenways can provide much-needed habitat for animals, especially in cities. In bustling cities, greenways can provide a relief from the stress of urban life. In less urban environments greenways can provide a safe alternative to travel along busy highways or country roads. As federal funds are made available for environmentally friendly transportation uses and as civic leaders are influenced by their constituents, more and more governmental entities are developing greenway projects.

Development of the Greenway Movement

Greenways are the natural development of an urbanizing society. Early precursors to greenways were wide streets, often tree-lined, with a median between the directional lanes. Parkways were the corridors that were bordered by parks or park-like surroundings. European cities were built on a grand scale and their tree-lined boulevards are ancestors of the modern greenway. Frederick Law Olmstead developed plans for the parkways that came to dot America's landscape. These were designed as sorts of linear parks and were for the pleasure of the traveler.

The early parkways were developed for horse-drawn vehicles. The Blue Ridge Parkway is a further development of the concept and provides hundreds of miles of scenic mileage. Some cities developed greenbelts as a way to buffer the city from the countryside. Unlike linear, narrow greenways, greenbelts could be very deep buffers to prevent the invasion of rural territory by the city. The

River Walk in San Antonio is a pedestrian parkway that, in many ways, foresaw the development of greenways along rivers.

Next came the development of recreational trails and parks bordering rivers, railroads, and other aspects of the city and country. In the 1970s the need to experience nature was becoming an important aspect of life. Local governments developed trails within their boundaries to give residents a way to escape, if but for a while, from the demands of the city. The use of the term *greenway* was developed during this time and may have been used first in Denver.

The city of Denver built a greenway along a river running through the municipality. This was the era of the effort to build bike paths in cities. The early environmental movement played a part in this era of the greenway movement, fostering greater efforts to experience nature. It was during this time that the Rails-to-Trails movement began. A changing economy and the advance of the highway system led to the abandonment of hundreds of shorter railway lines that were no longer economically feasible. Many of these abandoned rights of way held by railways have been turned into greenways. If the rails are still in place, they are removed and replaced by pathways with a variety of surfaces. Some are very short and some run for many miles, such as the KATY trail in Missouri. They provide recreational pathways with various uses.

The most recent stage of greenway development has seen a multiplication of purposes for new projects, including conservation of soil and wildlife, flood protection, recreation, and the beautification of town and country. Advances in the ecological sciences and civil engineering, along with other studies, have led to a more advanced level of greenway planning. Whereas earlier stages of the greenway movement had to do with aesthetics and recreation, more recent greenways add great environmental benefits to enjoyable and beautiful scenery. Some greenways help preserve and highlight important historical sites.

Purposes

One of the major purposes of an urban greenway is to provide a context for recreational activities. In a stressful urban world, people can be renewed by activities especially available in an environment where plants and animals exist in abundance and

where there are open spaces. Biking, walking, running, skateboarding, and rollerblading are only a few of the ways in which people are able to exercise and relax in a place like an urban greenway. One study found that 75 percent of trailway use is for recreational purposes. While the purposes of greenways have grown more diverse, at the heart of many greenways is the recreational benefit.

Even when the primary purpose may be environmental or cultural, the recreational benefit is still there. Sometimes the activities provided for may be what draws public support for the project. It is fairly easy to put in recreational trails in most greenways. Multiuse trails draw the largest numbers to a greenway. Sometimes crowding becomes an issue.

A more recent trend has been to develop greenways for the environmental benefit they provide. It might be that a stream or river often floods, and land that might have been used for crops or even for buildings can be repurposed as a floodplain. Most of the time, the land will not be flooded and will be available as open space and even for recreational use. Conservation of soil has gained more importance in recent years. Erosion causes the loss of valuable land and also the silting of rivers and streams downstream. The areas immediately adjacent to streams and rivers, when floodplains are not provided, are often poor habitats for native species due to the engineering that must be done along the bank.

Included in a greenway, less aggressive steps can sometimes be taken, allowing for a less disturbed habitat. Greenways provide habitats for plants and wildlife. Greenway corridors often provide means of access between larger tracts of habitat for wild animals. Animals are able to roam more freely and safely when these greenways connect larger habitats. Plant seed production takes place in greenways, thereby ensuring some additional natural source for plant reproduction. Greenways can provide a good buffer to noise and light pollution in urban areas and along roadways.

Due to the diversity of ecology in greenways and the attraction they provide for the public, they are now often used as outdoor classrooms and learning centers. Various educational entities use these outdoor habitats to encourage conservation and to equip individuals to be advocates for the environment and for the species that inhabit greenways. More recently, the greenway movement has



South Minneapolis's Midtown Greenway provides bicycle and walking pathways along 5.5 miles of a former railroad corridor. Organizers claim that biking through the unobstructed greenway can be a faster way to make short trips through the city compared to driving. However, one study has found that trailway use in general tends to be as much as 75 percent recreational.

expanded to include efforts to stimulate the economy of areas surrounding greenways. Since these spaces can provide a large draw of people to the area, they can be a boon to businesses that cater to the wants and needs of these visitors. Restaurants provide one example of such a business. People get hungry and thirsty as they exercise along a greenway. Restaurants and other outlets for refreshments at either end of the route, or adjacent to the route, can earn substantial revenue. Property values can even increase by being located on or near a greenway. This can activate investment and building near greenways. Of course, the increased investment in building can also have negative impacts on the environment. It would be ironic to see greenways lead to further environmental degradation.

Policies and Planning

Barriers to greenway establishment have to be taken into consideration in the planning process. Financing of greenways is a major issue. In an age when governments at all levels are cutting back on nonessential expenditures, the competition

for dollars can be a huge obstacle. Acquiring the land for a greenway can be time-consuming and very expensive. If a greenway project is to succeed, there must generally be strong support from the community. The cost-to-benefit ratio may be used by the public in deciding whether to support the greenway. If the public sees great benefit in the greenway, it may be more likely to support the expenditure of public funds for the project. Landowners adjacent to the greenway may present an obstacle to development.

Some fear a reduction in their property values, possibly through limitations on activities on their land near the greenway. Others fear that the greenways will cause a decrease in the security of their property due to the large numbers of people who may travel the greenway. There may also be resentment of the loss of privacy caused by the influx of people to the greenway. Some oppose any government action that places any restrictions on the use of private property. Sometimes greenway development will infringe on private property rights. Some have resorted to threats of violence

and even destruction of greenway infrastructure in their opposition.

When greenways are planned, the requirements of the Americans with Disabilities Act must be taken into consideration. Any barriers to those with disabilities, especially along pathways, should be mitigated. The complex purposes of greenways means that the planning process must be detailed and thorough. Since greenways accomplish much more than providing a scenic recreational venue, the other purposes must be carefully studied. An example, discussed below, is the Lafitte Corridor Greenway project in New Orleans. This project has been studied for years and a number of different planning documents have been prepared. One key lesson is that a multitude of factors must be considered and the planning process may move at an exceedingly slow pace.

Greenways with good pedestrian planning can aid the effort to create walkable communities. Proper zoning ordinances contribute to communities with regard given to walkers. Greenways can fill a valuable role in lessening dependence upon the automobile for local needs. Pathways in greenways should be kept as far as possible away from roadways. Special attention should be given to the intersection of greenways with roadways. These intersections may present a risk of serious injury risk for travelers using greenway paths. Isolation from roadways along most of the greenway can lead users to complacency when they do come into contact with motorized traffic. Proper signage and approaches are necessary to prevent needless accidents.

One avenue for successful greenway development is local action. In some areas, especially urban areas, neighbors have a deep desire to see any green space conserved. To prevent commercial development, neighbors may join together in an effort to establish a greenway project. Local initiatives have the best chance of success. A limited project in one neighborhood may spur adjoining neighbors to push for the project to extend to them. A greater greenway may result when several neighborhoods come together to protect the availability of a greenway for their particular neighborhood. The final result, after local and regional input, may result in a significant greenway.

In the face of economic constraints, future greenway projects will require unusual public support

if they are to succeed. Collaborative efforts are more likely to result in a completed greenway. The busy pace of life in both urban and rural communities will continue to point to the need for the slower pace of life in a greenway.

The Lafitte Corridor Greenway Example

An interesting greenway is being developed in New Orleans along a 3.1-mile right-of-way that is primarily owned by the city. A portion of the right-of-way once was the site of a shipping canal that connected a natural waterway, Bayou St. John, to the French Quarter. This canal was a means of transporting goods into the city. A railroad also occupied part of the corridor. The canal was filled in many years ago and the railway has been abandoned. Efforts to create a greenway have gained interest through the years, and after Hurricane Katrina the city made the Lafitte Greenway Corridor a priority. A comprehensive plan for the city, the Unified New Orleans Plan, noted that the corridor would have a high recovery value.

In 2007 the city council passed a resolution dedicating the city-owned portions of the proposed greenway for the project. The greenway would connect the historic French Quarter with the Lakeview neighborhood, which was hard hit by the flooding of Katrina but has experienced dramatic recovery. The proposed greenway runs through nine neighborhoods of New Orleans.

Beginning at an internationally known historical location like the French Quarter, such a greenway would draw much tourist attention as well as provide much-needed recreational space for locals. The greenway would capitalize on the cultural richness of New Orleans and its neighborhoods and also on the long history of the city, with the route following the old bed of a historic shipping channel. The route also starts near the site of Congo Square, which has much cultural significance.

The corridor's development includes the greenway itself and the neighborhoods within a quarter mile of the greenway. It is hoped that the greenway will be a catalyst for economic growth in the immediate surrounding areas. A 16-acre park is planned for the area as well as bike and walking paths. Numerous efforts have been made to gain public support for the greenway, including organized hikes along the route. These hikes have

raised awareness of the project and have probably advanced the effort.

An organization called Friends of Lafitte Corridor was created to provide support for the continuance of the project. The city council formed the Lafitte Greenway Steering Advisory Committee to aid the council with regard to planning and implementation issues. Members of the advisory committee are appointed by the mayor, city council, and Friends of Lafitte Corridor. Federal block grant disaster recovery funds provided to the state of Louisiana were made available to help fund the greenway project.

The city's Lafitte Corridor Revitalization Plan follows a number of other planning documents that were developed in an effort to see the greenway come to fruition. The plan notes that the very heart of the vision for the greenway is the trail that will be used by people who want to walk, run, and bicycle, and, in addition, by those who want to use a variety of other forms of recreational transportation, including horses. The project exemplifies many of the facets of greenway planning of the most recent era.

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See Also: Bicycles; Bicycling, Health and Recreational Aspects of; Rails-to-Trails Programs; Urban Trail Systems; Walking.

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Handicapped Access

According to federal law, physically disabled people must have equal access to education, employment, and health care. In order to comply with federal law, buildings and transportation systems must meet federal guidelines as specified in the Americans with Disabilities Act (ADA). Failure to comply with ADA guidelines not only results in segregation and disenfranchisement of the physically handicapped, it also can also lead to injuries, lawsuits, and loss of funding for public transportation systems.

For people with physical disabilities, accessibility and safety are primary issues when they travel. Access to public areas, such as city streets, public buildings, and restrooms, still remain a challenge for physically handicapped travelers. A noticeable change in some parts of the world are the installation of elevators, automatic doors, wide doors and corridors, bus lifts, wheelchair ramps, curb cuts, and the elimination of unnecessary steps where ramps and elevators are not available, allowing people in wheelchairs and with other mobility impairments to use public sidewalks and public transit more easily and more safely.

History

The wheelchair was the first major improvement to increase mobility for the physically handicapped. Wheeled beds and chairs first appeared in ancient

Greek and Chinese art in the 6th century B.C.E., but the first official wheelchair dedicated to the transport of a disabled person (called an invalid's chair) was made for Phillip II of Spain in 1595. A variety of three-wheeled models appeared in Europe after the invalid's chair, the most popular being the Bath wheelchair designed in 1783 by John Dawson of Bath, England. In the 19th century, inventors made improvements to the Bath chair to increase comfort and self-propulsion. In 1916, the first motorized wheelchair was built in London. In 1932, engineer Harry Jennings built the first folding, tubular steel wheelchair that served as a model for the type used today. Jennings built this wheelchair for his paraplegic friend, Herbert Everest. Together they founded the company Everest & Jennings, devoted to the mass production of wheelchairs. To this day, Everest & Jennings wheelchairs are still sold in folding, reclining, and motorized models. Motorized wheelchairs allow for maximum independence, as a physically handicapped person does not need to rely on physical strength to operate them.

President Franklin Delano Roosevelt, who became paralyzed from the waist down due to paralytic poliomyelitis, depended on braces, crutches, and a wheelchair for transport. During his time, the discussion of physical disability was taboo, and he refused to be seen in public or photographed with his braces or in his wheelchair. Roosevelt needed assistance to get in and out of the presidential

limousine, and his limo was driven onto a ramp to avoid steps. Roosevelt's staff also provided a ramp with railings for him when he traveled by train.

Though physically disabled people with means had nurses and servants to accompany them during travel and to provide accommodations, those of limited mobility in less fortunate circumstances often remained housebound or institutionalized, depending on the level of care they required. In the mid-19th century, however, physically disabled, visually impaired, and hearing impaired individuals began attending special schools to learn how to live functional, independent lives. Living skills included how to navigate through traffic and how to take public transportation if possible.

Unfortunately, the physically handicapped often still had to have people lift them out of wheelchairs or otherwise physically carry them onto buses and trains, something that was not only dangerous but also embarrassing. Vehicle operators would not allow guide dogs to ride, causing further stress to visually impaired people. Last but not least, hearing impaired people could miss their stop if no one provided a visual cue as to when to get off the bus, train, or subway. The first underground trains were often inaccessible for wheelchair-bound individuals, as few elevators existed to bring them underground, and trains were not designed with adequate spaces for wheelchairs. For these reasons, the physically handicapped remained separated from the rest of the population.

The Disability Rights Movement

Just as African Americans fought for their civil rights in the 1960s, people with disabilities also came together to make other Americans aware of how institutions segregated them from all areas of society. The disability rights movement adopted many of the strategies of the civil rights movement, including seeking justice in Congress. The historic shift in disability public policy began in 1973, with the passage of Section 504 of the Rehabilitation Act. Section 504 stated that recipients of federal funds could not discriminate against, or deny services to, anyone on the basis of disability. The Department of Health, Education, and Welfare was tasked with developing regulations to implement Section 504, providing guidelines to all other federal agencies. These regulations mandated affirmative conduct to remove architectural

and communication barriers for the disabled, and to provide accommodations. Public transit systems, however, were slow to make changes.

In 1978, disability rights activists in Denver, Colorado, organized a sit-in and blockade of the Denver Regional Transit Authority buses. The city's transit system at that time was completely inaccessible for the physically impaired. After several civil disobedience demonstrations in Denver protesting the city transit system, the Denver Transit Authority purchased buses with wheelchair lifts. Based on the success of this campaign, the leader of this movement, Reverend Wade Blank—a nondisabled former nursing home recreation director known for establishing the Atlantis Community to allow disabled individuals to leave nursing homes and live independent lives—founded Americans Disabled for Accessible Public Transit (ADAPT) in 1983 to expand the campaign for bus wheelchair lifts nationwide.

ADAPT protesters became infamous for their tactic of immobilizing buses. They would stop a bus in front and back, and wheelchair users would get out of their chairs and crawl up the steps of an inaccessible bus. For seven years, ADAPT targeted city buses and interstate bus services such as Greyhound as well as the American Public Transport Association to build awareness of inaccessible transportation. The ADAPT campaign ended in 1990 when the Americans with Disabilities Act mandated that all buses in the United States install bus lifts for people using wheelchairs.

Physically disabled people also struggled to obtain equal access to air travel. Passengers still had to climb up and down narrow portable stairs when getting on and off an airplane. Not only was this impossible for a wheelchair-bound person, but it was also very difficult for someone in braces. Depending on the severity of their impairments, disabled people could also miss their flights and transfers if their handicaps reduced their ability to move efficiently from one gate or terminal to another. In 1986, the Air Carrier Access Act was added to Title 49 of the U.S. Code.

The Air Carrier Access Act was passed by Congress in response to the Supreme Court ruling in *U.S. Department of Transportation v. Paralyzed Veterans of America*. The Supreme Court held that private, commercial air carriers were not subject to Section 504 of the Rehabilitation Act because they

were not direct recipients of federal funds. This act requires that the Department of Transportation develop and maintain regulations that prohibit commercial airlines from discriminating against passengers with disabilities. Air Carrier Access Act regulations were published in March 1990. They clearly state that carriers may not refuse transportation to a passenger on the basis of disability, that carriers must provide passage to any individual who has a disability that may affect his or her appearance or involuntary behavior, and that carriers may not limit the number of individuals with disabilities on any flight. All trip information made available to other passengers must also be made available to passengers with disabilities.

The Americans with Disabilities Act

In 1990, the Americans with Disabilities Act (ADA) became law. ADA Title II addresses public transportation services, such as city buses and public rail transit. Title II states that public transportation authorities must comply with requirements for accessibility in newly purchased vehicles, make good faith efforts to purchase or lease accessible used buses, remanufacture buses in an accessible manner, and, if possible, provide paratransit, a service whereby individuals incapable of using the regular transit system due to physical or mental impairments are picked up and dropped off at their destinations.

ADA Title III addresses public accommodations, which include privately operated transportation and transportation depots. Title III restates that public accommodations must comply with basic nondiscrimination requirements that prohibit segregation and unequal treatment. It stresses that reasonable modifications to policies, procedures, practices, and buildings themselves must remove barriers to communication and mobility for people with hearing, vision, or speech disabilities.

Improvements to Transit for the Disabled

The United States has become a model for improving access to transportation for those with disabilities. These accommodations, federally mandated through ADA, have become a part of the American landscape and improve everyone's travel experience. The greatest improvements to handicapped access to transportation are ones that all Americans now take for granted when they travel.

Street intersections that have traffic lights must also have traffic signals for pedestrians. Pedestrians include wheelchair-bound people, as well as people in braces or those with other disabilities that affect their mobility. Traffic signals for pedestrians provide visual indication of when it is safe to cross the street, as well as the amount of time they have to do so. Some cities have begun to upgrade their pedestrian traffic signals to models that loudly announce whether a pedestrian should wait or cross. Intersections are often modified to include a ramp that will allow a disabled person to safely transition from the sidewalk to the street, then back onto the sidewalk on other side.

Vans now exist for wheelchair-bound travelers. They allow for at least one wheelchair-bound driver or passenger to ride. These vans come with a large sliding door, a ramp, and "tie downs" or a docking system to keep the wheelchair stable while the van is in motion. Some states provide wheelchair conversion services for those who own standard vans or minivans. A driver rehabilitation specialist—a physical or occupational therapist with education in disability driving issues—will assess a physically disabled person to determine what type of modifications they will need for the vehicle. The Association for Driver Rehabilitation Specialists (ADED) is the primary resource for drivers with disabilities, as well as family and caregivers of disabled drivers.

Not only must buses have ramps for wheelchairs but they also must have at least two seats for wheelchair access. After someone in a wheelchair enters the bus, the bus driver must fold up the designated seat to make space for the person in the wheelchair, then buckle a special seat belt to the bottom of the chair. Buses also have designated seating for elderly or otherwise disabled passengers; nonelderly and nondisabled passengers must yield these seats if asked. Certified service animals wearing service attire are allowed to accompany disabled passengers on the bus. Bus drivers will also apply the wheelchair ramps for the elderly, those carrying heavy packages, and anyone who looks too tired to climb the bus stairs. Buses are now programmed to provide announcements on a monitor that people can see, as well as voice announcements, to let people know when the bus is approaching a stop. Passengers ready to get off the bus do not have to stand or shout to inform the bus driver of their intentions;



The San Diego Trolley, in San Diego, California, is equipped with a handicapped and wheelchair elevator extended to serve waiting passengers at the city's Old Town Station, 2006. While some U.S. cities have completed upgrading all of their subway and train stops to make them handicapped accessible, a number are still in the process of ensuring consistent rail transit access for the disabled population.

instead, they can pull a string or push a button to let the driver know when and where to stop.

City bus systems that serve large disabled populations often have a Dial-a-Ride service. Interested riders must apply for this service and show proof of their disability from their doctor. Dial-a-Ride is particularly ideal in northern cities, when snow banks may limit access to bus stops for the physically disabled. Bus depots provide bus schedules at wheelchair level, and some have renovated their customer service counters so that someone in a wheelchair does not need to depend on another person to facilitate the bus fare exchange.

Subways and trains provide passengers maps that indicate which stops have handicapped-accessible elevators. Some cities have made all subway and train stops handicapped accessible, while others are still in the process of upgrading these stops. Each subway or train car has at least one space for

a wheelchair near the door, as well as designated seating for elderly or otherwise disabled passengers. Just like buses, subways and trains also have labeled seating by the door for elderly or otherwise disabled passengers; nonelderly and nondisabled passengers must yield these seats if asked. Certified service animals wearing service apparel are allowed to accompany disabled passengers on subways and trains. Subway cars often have maps and stops clearly posted in the line of sight for all passengers, provide announcements about upcoming stops or service changes on a monitor that people can see, and use voice announcements.

Air travel remains a challenge for wheelchair-bound passengers. The greatest improvement to air travel for the physically disabled has been the commitment to getting people with limited mobility to their flights on time. Terminals have special shuttle services for the elderly and disabled so they reach

their gate in a timely fashion; they also provide folding wheelchairs that will fit on the plane. People with disabilities have the right to pre-board the aircraft prior to all other passengers. The Air Carrier Access Act of 1986 allows service dogs or emotional support animals registered with the National Service Animal Registry who have written proof of certification and service-appropriate apparel on airplanes without a fee. Most terminals have done away with transportable stairs; instead planes are aligned with a portable tunnel that allows passengers to board/disembark from the airplane and walk or ride their wheelchair into the terminal. Restroom access and seating on airplanes still remain challenges for wheelchair-bound passengers, as passenger planes still have limited space for movement.

Wheelchair-bound travelers, as well as those with service animals, are required to provide notice to the airline of their conditions so that reasonable accommodations can be made, especially during cross-country and international flights. Some disabled passengers with service animals believe that some airlines deny them reservations, so this still must be resolved.

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See Also: Accessibility and Mobility; Aircraft Design; American Public Transportation Association; Americans With Disabilities Act of 1990; Automobile Design; Automobile Drivers, Disabled; Bus Design; Dial-a-Ride; Disabled Driving and Vehicle Modifications; Elderly and Disabled Travelers; Paratransit in Developing Countries; Transit Fares.

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Harbor and Port Planning

Ports are links between the sea and the land (or rivers and land in some cases). Harbors, by contrast, are sheltered areas along a coastline where ships and boats can anchor for protection in bad weather or high seas or be moored for long periods of time while their owners are elsewhere. Harbors can be naturally occurring areas or human-made structures, where sea walls and breakwaters provide additional shelter for boats using the harbor.

Many factors are involved in the planning for harbors and ports. Is it an existing harbor or port that needs to be extended, or is it completely new and being built in response to economic factors such as changes in global trade routes? Is the harbor in a sheltered area with room to expand or does it require human-made breakwaters to be built? Is there room for expansion if the port is surrounded by a town or city? Are industries around the port closing down, giving scope for it to obtain additional land for expansion? How good are the road and rail links to transport seaborne goods and passengers from the port? Is the port capable of accommodating the ever-larger ships or does it need new quays, berths, cranes, and other equipment? Are there other nearby ports competing for the same business? These are just some of the questions that might be asked when planning change in a port or harbor, but they are not the only ones.

There are many different types of ports and harbors, each with a unique history and ranging from tiny ports receiving only a few ships each year to massive container terminals that receive the largest container ships and from ports where small numbers of people use foot ferries to the largest passenger ports where several million passenger journeys are made annually. As a result, harbor and port planning needs to take into account a range of factors, such as national or regional regulations, as well as environmental issues and the concerns of local stakeholders, including local councils, road traffic planners, tourist agencies, local residents, and nongovernmental organizations where there are environmentally sensitive areas.

Irrespective of whether it is a historical port, small or large, or a new port is being planned, the main emphasis should be on ensuring that port

users benefit from high-quality services, that those services are carried out efficiently and effectively, and that there is little or no delay for ships arriving, discharging or loading cargo and passengers, and departing from the port area.

Port Planning for Existing Ports

Historical ports can be viewed as being at a disadvantage in terms of planning for expansion. They may be limited in how much they can expand physically or how much new infrastructure can be brought on site. As an example, the largest cranes may not fit within the existing port area, meaning that the largest container ships could not be unloaded, even if the water channel and access were dredged to make it deep enough for those ships to access the port. In a river port, where the banks of the river are built up with a mix of industrial activities and housing, for example, or where there are quays and jetties along its banks, it may not be possible to widen the channel and so the geography of the port is a physical barrier to expansion.

Another factor to consider is who owns the land on which the port is built. Is it a private port, where all the land, infrastructure, and services are owned and operated by a private company or is it (less commonly) a public port, where the national or municipal government owns the land and infrastructure and carries out all the operations (or is it some combination of the two)? Who administers and operates the harbor or port will have a major impact on what it can do to change, including where the funds required will come from. Potentially, publicly owned ports will find it easier to gain permission for planned developments, but they may find it harder to get funding than does a private port, where the aim is to make a profit for the shareholders and a case for development can be justified as being needed to keep the port operating in a profitable manner. However, obtaining permission to develop the port area may be more difficult for the private port owner.

Historical ports and harbors do, however, have an advantage from the relationships developed over time with municipal or local government agencies, national government, local communities and businesses, and also, very importantly, with shipping companies that have used the port for many years. Though a port may not be able to accommodate the largest ships, it can still provide services for

the range of ships that do not require more space. In port planning it is therefore important to consider the existing port users and how to provide the services they need to make their businesses more efficient. This can include improving maintenance or repair facilities for ships in port, for example, if any minor deficiencies are identified during a ship inspection. It can also include better warehousing for goods (including bonded warehouses for alcohol, cigarettes, etc., and secure areas to store consumer electronics, for example), packing facilities where cargo can be broken down for delivery to various destinations, and access to facilities in the port for ships' crews (banking, Internet connections, shops for clothes and toiletries, for example). It can also include measures to improve local road or rail links so that cargo can enter and exit the port more quickly or provide dedicated areas for the use of a single company.

Another way to improve services, particularly in ports where working hours are limited by local restrictions, is the renegotiation of hours with local authorities as a way of retaining current port users. However, anything that may impact the local community (such as extending hours of operation) should involve discussions with the local residents or businesses to ensure they are supportive of the proposed change. Particularly if the port faces a loss of business and therefore impacts the income entering the local economy, it is also important to have public involvement in port planning because the community will also suffer from lost business.

Diversification of business activities taking place in the port and in the types of shipping or cargo companies using it may also need to be considered to bring in new business, particularly if current port users move toward containerization and move their operations to a container port, for example. In that situation ports may need to consider downsizing the area they cover by selling off land or buildings for housing or change the use of part of the port area for other activities.

Another area that historical ports can consider in port planning is working in cooperation with other ports nearby or within the region or building new terminals near its existing location. In the former case, particularly in regions such as northern Europe where there are many ports in close proximity, a cooperative approach whereby those ports combine their operations may be considered.

If there is room for expansion farther along a coast, the port may build new infrastructure and provide links by road, rail, or water between the new development and the old port area. New cargo-handling equipment and other facilities for ships could be provided in the new terminal area, while the existing area could be developed to contain administrative activities, maintenance or ship repair services, long-term storage facilities, or any activities that do not have to be at the ship–shore interface.

Planning and Building New Ports

Many new ports have been built in response to changing global trade routes for shipping, for example, with the opening up of markets for goods manufactured in China and southeast Asia and traded to Europe and North America. The result has been the development of a number of new very large ports capable of handling the biggest container ships in the Far East. It has also resulted in new ports in other areas, such as the port of Jebel Ali, Dubai, United Arab Emirates, which was built around a small port town and covers an area of approximately 52 square miles (134 square kilometers). At the time of building, Jebel Ali was the world's largest harbor and one of the largest container ports in the world.

In the building of new harbors and ports, local conditions play a part in port planning, including weather conditions, prevailing winds, and tides. If a port has not been built in the area before, what are the reasons? Is the area unsafe? What would need to be done to make it safe for ships using the harbor or port? Consideration must be given to accessibility—is the waterway or coastal area deep enough and wide enough to accommodate the types of ships that will want or need to use it. If it is not, can dredging make the area accessible and, if it can, how frequently will the channel need to be dredged to maintain access?

Another question to consider is whether there are any environmentally sensitive sites or endangered species in the area where the harbor or port is planned. If the answer to that question is yes, port planners may need to consider whether any changes to the plans can be made and how those species or areas can be protected. They may need to work with environmental nongovernmental organizations (NGOs) or other groups in planning the port area and may also need to justify the need for it to the wider community.

Ports offer employment opportunities, not only during construction but also later for dock work, office work, transport firms, and other businesses. As a result, planning for new ports (or new terminals) needs to consider whether a suitable workforce is available locally or whether it will be necessary to bring people in from elsewhere. It also needs to consider whether adequate housing for employees and their families, hospitals, schools, shops, and services already exist nearby or whether these will have to be built nearby. Transportation links by road and rail also need to be provided, not just for cargo use but also for the people working or living around the port.

Other factors that need to be considered in port planning relate to the efficiency and competitiveness of the port. If a new port is to operate in direct competition with others in the same area, country, or region, how can it stand out from that competition and attract new business? In this situation, size may play a part if it is the only port that is accessible to the largest ships. In addition, factors such as the services provided to port users, the speed of throughput of cargo from ships to shore, whether there are adequate connections and intermodal transport links from port to the hinterland, or whether new links need to be built and, if so, where they can be built also need to be considered. It is also important that the port (old or new) works in cooperation with local government agencies and national government while planning changes and developments, as their agreement is vital if change is to be achieved. Ideally, ports will work with local communities and other stakeholders in port planning to ensure they accept any changes, as their opposition has the potential to damage the port's image.

Conclusion

The main considerations in port planning are ensuring that the harbor or port is profitable and attractive to port users, that it provides all the services necessary in an efficient way and with the appropriate equipment needed to do so, and that the port is accessible from the sea and has adequate links by road or rail to the hinterland. In the planning of a new harbor or port, it is important to identify the target users and involve them in the planning process to ensure that their specific requirements are met during the development of the port area. For

historical ports, identifying target users and working to meet their needs is important, both to retain business and to bring in new business. Cooperation with stakeholders such as local and national government, local businesses and communities, and other interested parties is also necessary to ensure that planned development is supported and that good relationships exist between the port and its neighboring communities.

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See Also: Container Terminals; Containerization/ Container Shipping; Environmental Impacts; Freight Terminals; Harbor and Port Security; Harbors, Design and Engineering of; Harbors and Ports, Administration and Operations of; Port Inspections; World Container Ports.

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harbors used by fishing vessels, small cargo vessels, or passenger vessels. Although the words *ports* and *harbors* are frequently used interchangeably, they are not the same: a harbor is an area of sheltered coastline (whether natural or human-made) where ships can moor and be protected from bad weather; a port has equipment for loading and unloading ships. The world's major ports and harbors are hubs in the global transport of raw materials and manufactured goods and often also serve as hubs for passenger travel and the transportation of livestock. United Nations statistics indicate that around 90 percent of all goods traded internationally were transported by sea in 2011, with the top 20 container ports handling more than 55 percent of those goods. As a result, ports and harbors may be viewed as a target for terrorist attacks, as well as destinations for smugglers. Port security is an issue of global concern, and therefore technologies are being developed to make them safer from threats from both land and sea.

Harbor Security in a Post-9/11 World

Security of ports and harbor areas became an issue of growing concern in the wake of the September 11, 2001, attacks on the United States. Previously, security in ports was often directed at land-side threats such as the theft of cargo from ships, containers, or warehouses, and at securing the long perimeter fences to prevent individuals or groups from breaking in and stowing away on ships. Security perimeter fencing is a particular problem in ports situated adjacent to urban areas, where individuals can hide and wait for the opportunity to enter the port. Security issues in harbors were theft from or of vessels tied up overnight, for example.

Following the 9/11 attacks, a number of initiatives were introduced to provide greater protection from potential terrorist attacks on ports and the ships using them. Those initiatives included the International Ship and Port Facility (ISPS) Code, a set of measures introduced in 2004 as part of the International Convention for the Safety of Life at Sea (1974). That code places legally binding requirements on both ships and ports to ensure their security, together with recommended measures that allow them to go above and beyond the legally binding requirements should port characteristics require it. Under the ISPS Code all ports are required to prepare a Port Facility Security

Harbor and Port Security

Industry statistics from World Port Source indicate that there are at least 4,700 ports in 196 countries around the world, with more than 430 ports in the United States and more than 1,500 in western Europe. This figure does not include marinas for pleasure vessels or the many numerous smaller

Assessment conducted by a recognized security organization. Once that assessment has been carried out—examining the physical security of the port, its structural integrity, personnel protection, and transportation infrastructure, for example—and potential security threats have been identified, a Port Facility Security Plan must be developed to create a secure port environment.

The Port Facility Security Officer is responsible for maintaining an up-to-date security plan that includes the following: who can access to the port and how to identify them (for example, by using differently colored badges to identify employees or nonport workers such as truck drivers, and maintaining records of who holds badges); how to ensure the physical security of the port, including fences, office buildings, warehouses, and utilities, using security patrols, additional lighting, or specialized equipment; establishing water-side measures to prevent or minimize the threat from drug or other smugglers and stowaways on ships in port, or from small boats being used to attack military vessels if they regularly visit a port, and use of underwater security systems; identifying who should be contacted in the event of security breaches and maintaining contacts with local or national law enforcement agencies, security services, the military, border control, and customs; and identifying any specific risks in the port, in particular if the port receives ships carrying hazardous materials or chemicals, crude oil, liquefied natural gas (LNG) or liquefied petroleum gas (LPG) so that additional security can be provided when those ships are in port. In relation to drug and explosive smuggling, the security plan may include the provision of canine search teams at access points to the port and at points where containers are transferred from ship to shore and from shore to road or rail transport.

A second initiative was the U.S. Container Security Initiative (CSI), introduced in 2002, which established a system of prescreening containers in foreign ports prior to their departure to U.S. ports. CSI operational ports include many of the largest container ports by volume of cargo, with ports from around the globe participating in CSI agreements. This system includes systems to identify high-risk containers based on information about their contents. Containers are screened using direct physical inspection or the use of monitoring equipment such as x-ray machines, gamma ray machines, or

radiation detection devices. Containers may also be sealed with high-security mechanical seals or with electronic seal or antitamper technology, and they may also carry Global Positioning System (GPS) data receivers so they can be tracked at all times. The system has the benefit of improving the security of ports participating in the initiative, as it offers an extra layer of security and expertise to those ports.

Smuggling

In addition to the potential terrorist threat to ports and harbors, a number of other threats, in the form of criminal activities by organized gangs, also exist. Smuggling by sea is an effective route into the lucrative markets for drugs and other substances in western Europe, North America, and Australia, for example. Large quantities of Colombian cocaine are transported into Europe. Some of that cocaine is transported by sea to west Africa and then by road to ports on the Mediterranean coast, where it is loaded onto ships sailing to southern European ports. Some of it may be routed either directly from South America or via the Caribbean into northern Europe. In the case of Asian heroin, the main smuggling routes are from the poppy fields of southeast Asia into Australia, or from via Chinese ports across the north Pacific Ocean into the United States.

Drugs have been concealed in cargo such as concrete blocks and bananas, in vehicles being transported by sea, in the tires of such vehicles, or in mechanical equipment that would need to be disassembled in order for it to be thoroughly inspected upon arrival in a port. Drug smugglers also use small ships that discharge their cargo along unmonitored coastlines or at smaller harbors where there is a limited security presence, as even a small ship can carry drugs worth many millions of dollars. Additionally, with the vast numbers of containers transported by sea each year, Hugh Griffiths and Michael Jenks suggest that criminal organizations will take advantage of what is a simple, convenient, and cost-effective mode of transport to smuggle narcotics, tobacco, counterfeit goods, weapons, and undocumented migrants by sea.

Other examples of smuggling include vast quantities of cigarettes and tobacco smuggled from China into the European Union, with European Anti-Fraud Office statistics suggesting that this trade cost EU taxpayers over 10 billion euros per annum. There is also a global market for smuggled



A U.S. Customs and Border Protection marine unit patrols the Port of Miami, Florida, in 2007. There are more than 430 ports in the United States alone. With approximately 90 percent of all goods traded internationally being transported by sea as of 2011, and at least 4,700 ports operating in 196 countries around the world, port security is a significant undertaking in many nations.

weapons, with examples of organized crime groups that smuggle weapons such as antitank rocket launchers and antiaircraft equipment from eastern European into southern European ports. There are also examples of assault rifles and submachine guns being discovered in containers on ships in Mediterranean ports that are destined for the United States, those discoveries being made when the ship has been inspected for a completely unrelated reason.

Human beings are also smuggled around the world, with examples of undocumented migrants from the Indian subcontinent and southeast Asia stowing away in containers on vessels heading to Australia and the United States. While many such stowaways may simply be seeking a better life, organized criminal gangs may also be involved in human trafficking, where individuals not only pay for passage and documents upon arrival at their destination but are then further exploited by being forced to work for the gang as laborers or domestic

servants, for example. Some stowaways may also be drug couriers who agree to carry small amounts of drugs in return for assistance in stowing away on a ship, while others may be professional couriers who make regular journeys and are very familiar with places to hide on board and how to avoid capture once a ship arrives in port.

Underwater Security

Although security in many of the largest ports has been increased in response to a possible terrorist threat, there remains the potential threat from underwater. This may involve divers or submersible vessels such as submarines or remotely operated vehicles. Underwater mounted cameras can be used as a way of monitoring for these threats, particularly around high-risk targets. Another system being developed is the use of passive acoustic monitoring systems using hydrophones (underwater microphones) to listen for underwater movement. These

systems have been used by the military as a way of avoiding detection as they do not emit sounds, unlike the more familiar acoustic sonar systems that transmit a sound and identify the distance from the object based on the reflection of that sound. Passive systems have also been used by scientists to monitor ocean noises and track whales, for example. A passive system may prove particularly beneficial in harbor areas where there is little or no ship movement during nighttime hours and could prove useful in identifying submersible vessels because the noise generated by their motors is different from the noise of surface ships and boats. It may be more difficult to identify divers, particularly in busy port areas, and it is likely that a large number of hydrophones will be needed to operate such a system.

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See Also: Container Terminals; Containerization/ Container Shipping; Freight Transport, Security Issues; Harbors and Ports, Administration and Operations of; Hazardous Materials Transport; Intermodal Freight Transport, Technology and; Port Facilities; Port Inspections; Security, Transportation; World Container Ports.

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Harbors, Design and Engineering of

From ancient times, waterfronts have been places where news of other places was exchanged—places of commerce where goods were unloaded and loaded and where mariners and passengers embarked on ships and disembarked in safe harbors. Waterfronts were cosmopolitan places where locals met foreigners and where sailors searched for entertainment. Even the smaller harbors were bustling centers of maritime commerce.

Harbors are just as important today. Oceanographer Robert Stewart of Texas A&M University writes in his online book *Our Ocean Planet: Oceanography in the 21st Century* that small ports and harbor facilities need to grow from supporting local consumption-only economies into export economies that fuel economic growth in the 21st century.

Nature is the primary designer of harbors, but as people settled on waterways in increasing numbers, waterfront commerce became an essential part of local, regional, state, and national economies and people have helped nature shape harbors, ports, and waterfront districts. Harbors and ports function interchangeably. A harbor shelters ships and berths them. A port is a place where ships can

load and unload cargo and passengers. Waterways, ports, and harbors often face the common challenges of sedimentation of waterway entrances, failing infrastructure, wave agitation inside mooring basins, degradation of water quality, and navigation challenges from water conditions and other vessels.

The U.S. Army Corps of Engineers has been the primary designer and engineer of harbors in the United States since the 19th century; in addition, many private harbor and port engineering companies plan and implement development every year, including facilities and dredging. Waterways in the United States face new challenges in the 21st century as they accommodate container ships and implement new safety measures against terrorism.

Designing and Engineering Harbors

Modern methods of harbor design usually begin with engineering drawings and a development program after evaluation of site conditions and coastal features like winds, waves, and storm protection. Part of the development plan includes a project vision, objectives, market conditions, and often marinas, boat ramps, and waterfront parks as well as marine structural inspection, design, and rehabilitation. Dredging and disposal plans and ecological restoration and habitat creation are also part of the engineering plan. When a plan is formulated and a contractor hired, the issues of shoreline stabilization, dredging, and coastal works design are addressed and federal, state, and local regulatory requirements are implemented.

Shoreline Stabilization

Federal, state, and local agencies work continuously to stabilize shorelines and harbors eroded by wind and waves and human alteration. For example, working within the Department of Commerce, the National Oceanic and Atmospheric Administration (NOAA) uses techniques built on a foundation sand fill. Combining these methods with low rock sills to keep harbors operational, they avoid harder structures like bulkheads, rip rap, or groins to create living shorelines.

Dredging and the Environmental Protection Agency

Sand and silt washing downstream gradually fill channels and harbors in a process called

sedimentation, which is a problem from small harbors to large harbor complexes like New York–New Jersey and Boston harbors. The U.S. Environmental Protection Agency (EPA) monitors dredging of harbors to remove and reduce the exposure of marine animals and humans to toxic sediments, a process called environmental dredging. Most dredging is done to maintain or deepen navigation channels; there is a growing need for wider and deeper channels in harbors because of the increasing size and use of container ships.

The EPA requires that before dredged material is approved for disposal, it must meet three requirements: (1) there must be a demonstrated need for the dredging, (2) the dredging methods and the disposal site of the dredged material must be analyzed, and (3) the material must be tested to ensure that it will not harm the environment.

Different types of dredges are used to remove sediment from harbors. A scoop-type dredge lifts a scoop at a time. A bucket dredge is a scoop-type dredge that has many buckets that travel along a boom on cables, with teeth inserted at the opening of the buckets to enable them to dig deeply into the material. The boom is maneuvered underwater so the buckets take a scoop of sediment and travel back to the barge to deposit their load. Bucket dredges can work on large rocks or sand; this type of dredging works best in distances like harbor approaches. A clamshell dredge has two sides that close to scoop large amounts of sediment. Clamshell dredges are often used in constructing harbors when boulders or other difficult materials need to be removed. They are slow but effective. A dipper dredge has only one side and is connected to a hydraulic arm. Dredging with a dipper dredge is slower than with a clamshell, but the dipper can fit into very tight spaces.

A suction dredge uses suction to draw water and sediment into a pipe, empty the material into storage compartments fitted with dewatering devices like seeps and overflows, and deposit the sediment into a designated area. A suction dredge moves material at a constant volume; some accommodate attachments that pull sediment into the suction pipe, others just use the pipe. A cutter head suction dredge has a large rotating collar fitted with cutters, or teeth, to break off and pulverize material before it is drawn into the suction pipe. The cutter head suction dredge can remove soft

rock and coral, and it is also used to clear rubble after blasting and clamshell dredging harder rock. The auger head suction dredge has a head outfitted with one or two large augers that are attached to the suction pipe at right angles. This dredge can cut a wide, shallow path. The augers rotate and pull material from the sides of the cut to the center, where it is vacuumed up by the suction pipe. The augers can also be fitted with teeth to remove material from the bottom.

The New York–New Jersey Harbor, the largest port complex on North America's East Coast, every year handles 2 million loaded containers—nearly half the North Atlantic total, including bulk cargo. The port complex generates about \$30 billion in revenues and \$620 million in state and local taxes. As with most other American harbors and ports, the economic health of the port depends on regular dredging cycles to keep berths open and navigation safe.

According to a 2013 Market Research Report from IBIS World Dredging Service, growth for the dredging industry has been lower than forecast, but the industry is expected to rebound over the next five years, largely because U.S. ports and harbors will require dredging to provide access for increasingly large container vessels.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) has created works “of a civil nature” in the United States, including water resources, since the 19th century. Through its Civil Works program the USACE conducts a wide array of projects that provide coastal protection, flood protection, hydropower, navigable waters, and ports. The Corps emphasizes navigation, hydroelectric power, infrastructure support, and emergency support activities.

Dating from 1824 federal laws that authorized them to improve safety on the Ohio and Mississippi rivers and at several ports, the Army Corps of Engineers today maintains more than 12,000 miles of inland waterways and operates 235 locks. The inland waterways—a system of rivers, lakes, and coastal bays improved for recreation and transportation—carry about one-sixth of the U.S. intercity freight at half the cost per ton mile of railroads or trucks. The USACE maintains 300 commercial harbors handling two million short tons of cargo a year, and more than 600 smaller harbors.

The Coastal Engineering Manual

During the past 50 years, the Army Corps of Engineers has based its coastal engineering practice on the *Shore Protection Manual* (1974, 1984). Previously the primary engineering manual was Technical Report No. 4, (1954, 1957, 1961, 1966), but these manuals do not reflect state-of-the-art technology and knowledge of coastal processes and engineering.

In the mid-1990s, the U.S. government, through the Coastal and Hydraulics Laboratory, initiated a *Coastal Engineering Manual* (CEM). The purpose of the CEM is to provide a single, comprehensive technical document that incorporates tools and procedures to plan, design, construct, and maintain coastal projects. The CEM includes basic principles of coastal engineering, methods for computing coastal planning and design parameters, and instructions on how to formulate and conduct studies in support of coastal flooding, shore protection, and navigation projects. The *Coastal Engineering Manual* is constantly updated and is the USACE's standard for the formulation, design, and projected performance of a broad variety of coastal projects.

Water Resources Development Act of 1986

The Water Resources Development Act of 1986, or the Deepwater Ports Act, authorized 270 Corps of Engineers projects, such as port development, inland navigation, flood control, stream-bank and shoreline erosion, and feasibility and reconnaissance studies for construction or study. The act covered all features of water resources development and planning, including federal interest cost sharing, environmental assessment, and mitigation requirements.

The act directed the Corps of Engineers to consult with the National Oceanic and Atmospheric Administration (NOAA) to determine how to use NOAA's capabilities to conserve fish and wildlife and to create and improve habitat for indigenous species. The act stipulated that all future projects undertaken by the Army Corps of Engineers had to include specific mitigation plans or proof that the projects would have negligible impacts on fish and wildlife.

The Reincarnation of Boston Harbor

Oceans and lakes have historically been used as dumping grounds, and removing sediments that

have accumulated over decades and even centuries can be challenging. Harbors such as Boston Harbor have an environmental legacy from industries that poured waste into them for a century. Boston, known because it had “the dirtiest harbor in America,” was sued in the early 1980s because of pollution in the harbor. Because of the EPA and other federal, state, and local agencies and private citizens, sources of pollution have been reduced. Industries have built secondary wastewater treatment facilities and no longer release sludge in the harbor.

In September 2000, the outfall pipe carrying treated wastewater through a tunnel out 9.5 miles into Massachusetts Bay went online. The Massachusetts Water Resources Authority has since invested more than \$30 million in specialized discharge and oceanographic monitoring and in studies of water and sediment quality and health of marine species. The ongoing work has been examined and reexamined by regulatory agencies and an independent panel of scientists. More than 300 technical reports and more than 1,000 scientific papers about Boston Harbor and Massachusetts have been published since the new treatment facilities were brought online.

Container Ships: The Future of Ports—Can Harbors Accommodate Them?

Container shipping, computers and the Internet, and a new geographical configuration of world trade, have dramatically changed the relationships between harbors, ports, and cities. Dating from the 1950s, container ships are cargo ships that carry their entire load in intermodal containers—truck-size containers that can be transferred from one type of transportation to another—without being unloaded.

Container ships carry two main types of dry cargo: bulk cargo and break bulk cargo. Bulk cargoes, such as grain or coal, are usually carried unpackaged in large volumes in the hull of the ship. Break bulk cargoes are generally manufactured goods and are carried in packages. Before containerization, break bulk cargos were loaded and unloaded from the ship one piece at a time, but by putting cargo into containers sized from 1,000 to 3,000 cubic feet or up to about 64,000 pounds, cargo can be moved at once, and each standardized container can be interlocked and secured to the ship. Containerization has increased the

efficiency of moving break bulk cargoes by reducing shipping time by 84 percent and costs by 35 percent. According to the *United Nations Review of Maritime Transport 2012*, world container traffic through ports in 2011 increased to 572.8 million 20-foot equivalent units (TEUs), the highest amount ever.

The trend in both national and world shipping is toward the use of container ships, which require high-capacity container ports and harbors. This means each local port must meet certain technical conditions that include deep-water channels, extensive areas of level ground for storage and intermodal transfers, and adequate rail and motorway connections to population centers. Cooperation among local ports, government agencies, private firms, and civic groups is necessary to transform local ports to accommodate the new, larger container ships and to create new urban uses such as offices, housing, or recreation in or near the ports, whether by remodeling, reconstruction, or new construction.

Global transnational shipping corporations and their partners who strive for economic efficiency must cooperate with local government business and civic agencies to develop the local economy and to improve the quality of the local public environment. They have to negotiate with each other for agreement about harbor and port improvements. Urban planning professor Hans Harms argues that harbor improvements lagged in San Francisco because the regulatory and governing structure is extremely complicated, the income-generating possibilities remain limited, and the state harbor commission has no strong leadership.

The Burton Act of 1968 transferred authority over the Port of San Francisco from the state of California to the city of San Francisco in 1969, but the city did not take decisive action. With this transfer, responsibilities were divided among various authorities with different constituencies, and as a public agency, the Port of San Francisco was responsible for the port area and the San Francisco city planning commission was responsible for the adjacent areas. Many of the project proposals included both areas and required the two agencies to agree.

The Port of San Francisco’s specific task is to promote activities like shipping and fishing, to protect public access to the water, and to preserve the environment, but its planning power is restricted and it cannot issue bonds. Under the Burton Act, the Port

of San Francisco is supposed to generate its own income from port operations and upgrade the run-down infrastructure without any support from the state or city. Port property can never be sold or used for private purposes, and San Francisco's municipal zoning and general planning policies apply to properties adjacent to the ports, so the Port of San Francisco's revenue generation from anything other than narrowly defined port uses is restricted. San Francisco does not have a facility plan or a policy development plan.

In contrast, the Port of Oakland located across San Francisco Bay formulated a strategic plan and took initiatives to expand and attract container shipping lines. A board of port commissioners governs the Port of Oakland, nominated by Oakland's mayor and appointed by the city council. The board has broad authority to oversee the Port of Oakland's maritime cargo operations and income from port properties. Oakland's authorities had a clear mandate and the power to make the port viable economically. Oakland's port has expanded and modernized and it is the dominant container port in the Bay Area. It ranks as the fourth-largest container port in the United States and handled 2.4 million TEU in 2006.

A New Configuration of World Trade

In the first decade of the 21st century, 85 percent of the world's goods, services, and capital investments are exchanged among the three economically most powerful regions in the world: western Europe, North America, and Asia. International container volumes have increased from 47 million TEU in 1996 to more than 140 million TEU in 2008.

North America is the third-largest import market for containers at 21 million TEU, behind Asia at 40 million TEU and Europe at 30 million TEU. The trans-Pacific trade routes have the highest trade volumes (22 million TEU at 10 percent average growth rate), with 17 million TEU at 12 percent growth rate for the Far East to Europe. North America imports more containers than it exports; forecasts for growth in the U.S. container trade are greater for imports than exports.

These trends have important infrastructure planning implications. Terminals, railroads, ports, harbors, and shipping companies will be required to make major investments as the industry continues

to mature. Today, as ports, harbors, and waterways prepare for the megaships of tomorrow, improvements and expansion of ports and their harbors require informed strategies and careful planning for successful implementation.

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See Also: Dredging; Environmental Impacts; Harbor and Port Planning; Harbors, Environmental Impact of; Harbors and Ports, Administration and Operations of; Port Facilities; Ships; World Container Ports.

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Harbors, Environmental Issues of

Harbors and ports have historically faced problems of pollution caused by waste dumped from ships, including oil, sewage, and garbage. As early as 1543, during the reign of King Henry VIII, bylaws were introduced in some United Kingdom ports to combat harbor pollution, with fines imposed on ships caught dumping oil. With growing awareness of the environmental impacts of pollution during the 20th century came the introduction of the International Convention for the Prevention of Pollution From Ships (MARPOL) in 1973, one of the earliest international environmental conventions. A convention of the International Maritime Organization (IMO), it establishes rules to prevent ships discharging wastes (oil, noxious liquids, harmful substances, sewage, and garbage) into the sea, with limits on how close to shore they can discharge substances, areas where dumping is completely banned, and also limits for some substances.

More recently, the MARPOL Convention has also set limits on the discharge of gases into the air. For ports, that convention lays down requirements that facilities be provided for ships to discharge waste while in port, and it has gone a long way toward reducing operational pollution from ships in port. However, harbors and ports also face problems with pollution from nonoperational sources and from dredging, often a necessity to ensure that ships can continue to access them.

Water Pollution

Water pollution can take many forms. It can be caused by ships deballasting (discharging ballast) before being loaded for a voyage. Ships use ballast to maintain stability during a voyage from one port to the next. They take water on board from one region and travel to another, where they discharge it before taking on cargo. However, a major concern with ballast water is that it can contain aquatic organisms, examples of which include jellyfish, zebra mussel, small crustaceans, and phytoplankton that are not native to an area and for which there are no natural predators. This has become an increasing problem with larger ships traveling greater distances more rapidly. With faster journeys, organisms are more likely to stay alive long enough to infest another region.

Ballast water can also contain toxic substances, such as heavy metals, chemicals, and oily substances that are suspended in the water being taken on board. Ballast has also, in the past, included the use of large stones taken on board in one country and thrown over the side when the ship arrives at its destination. While not necessarily as great a problem as the organisms and toxic substances in ballast water, those stones can still cause problems in ports, particularly if they are deposited in sufficient numbers to alter currents, tidal flows, or cause a physical blockage.

Another cause of pollution in ports is the deliberate discharge of waste from ships, despite international action to prevent it. In many ports, particularly in developing countries or countries where environmental protection is not high on the agenda or in very poor areas, it remains the practice for waste to be dumped into the water. This may be in a river where the waste washes down to the sea, or it may be in a port or harbor where dumping is quick and easy or there are no

facilities into which the waste can be discharged. Oily water is produced in the engine rooms of ships and small boats, and it has been common for this to be thrown into a harbor; many small fishing harbors may have a dark ring around them at the high-water mark, which is the result of floating oily waste being left behind as the water level drops. Other things dumped into the water include garbage, plastics, packaging, old fishing nets and floats, together with sewage and the remains from fish processing done at the quayside.

Industrial and urban runoff can also be a problem in ports and harbors at the mouths of rivers and estuaries. Runoff occurs when a substance such as oil and other substances in engine exhausts from cars and trucks is deposited on the ground and then washes into a river when it rains. This may be a particular issue in areas used by large numbers of trucks, such as large industrial ports or container terminals. Other pollution from cities and towns can include garbage and litter, blown or washed into rivers by wind and rain, and sewage waste (either treated or untreated). Many industrial processes cause pollution, and industries have often, historically, been situated on the banks of rivers that have been used to transport raw materials to, or processed/finished goods from, those industries. Agricultural runoff is also an issue in many areas. Here, animal wastes can be washed from pastureland into the rivers and transported downstream; fertilizers, pesticides, and other chemicals can be washed off arable land in the same way.

While some of the water pollution in ports is visible, such as rings of oil at high-water marks, or floating plastic and other debris, much of the waste is invisible. In areas where there is little water movement, a situation in many ports and harbors, waste sinks to the bottom of the harbor and accumulates over time, and action may be needed to remove that material.

Dredging

Dredging is the use of scoops, suction devices, or other methods to remove material from underwater. It takes place in many harbors and ports, particularly where large volumes of sediment are deposited through tidal or river action, reducing the depth of the water and making it more difficult for ships to gain access. It can also occur in new harbors or ports where large volumes of material have



Floating garbage like these pieces of plastic washed up on a black rock shoreline on the island of Hawai'i are among many forms of visible water pollution affecting ports and harbors. Other types of pollution may be invisible, such as toxins found in sediment.

been removed to create an area deep enough for use by very large ships but where tidal flows bring sediments back into the port area.

Sediment can simply be large amounts of silt (fine particles of soil or sand) that is suspended in the water columns of rivers and tidal estuaries, for example, and sinks to the seabed in sheltered areas such as around a sea wall, breakwater, or jetty. However, sediment can also be contaminated by mining spoil (waste material from mines) or from naturally occurring heavy metals that are washed out of the ground and into watercourses traveling to the sea.

Other sediments can contain high levels of organic material or fertilizers washed off agricultural land or from upstream urban sewage works and industrial and urban runoff. Some studies have found a range of chemicals in sediments, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins, and organotins. Many ports and harbors also have residues from

protective coatings painted on the hulls of ships to prevent rusting and corrosion, together with anti-fouling paints containing tributyltin (TBT), a substance used to prevent the growth of organisms such as barnacles that might slow the ship down. These substances leach into the water and are toxic in high concentrations. Although TBTs have been banned for many years, they will have entered sediment layers over an extended period of time.

Historically, contamination of sediments also has occurred in ports closely linked with urban areas, as well as those used by ships transporting metal ores, coal, and other loose cargo. When a cargo is unloaded and the ship needs to be cleaned to receive another cargo, material can be washed overboard during the cleaning process and sink to the seabed in the slow-moving water of the port. Dredging disturbs the sediment and releases particles into the water column, which can transport it over a wide area. If the sediment is contaminated in some way, it can damage ecosystems around ports and enter the food chain as it is bio-accumulated in shellfish such as oysters that feed on suspended matter in the water column.

Balancing the need for ships to be able to access a port or harbor with the potential environmental impacts of dredging can be a complex problem, particularly in ports with historical contamination. Careful assessment of the area, including tidal flows, seasonal conditions, and which materials are in the sediment, together with an analysis of the local ecosystem may be necessary.

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See Also: Dredging; Environmental Impacts; Harbor and Port Planning; Harbors, Design and Engineering of; Water Pollution.

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Harbors and Ports, Administration and Operations of

A harbor is generally a sheltered area along a coastline, in a lagoon or at the mouth of an estuary, or in a semienclosed inlet where natural formations have created a narrow entrance. Such harbors are deep enough for vessels (ships and boats) to anchor or seek shelter from weather, tides, or difficult sea conditions, and in some instances vessels may be left at anchor for long periods of time or make more frequent journeys using the harbor as a base from which to sail (for example, fishing boats or small cargo boats and foot-passenger ferries).

Generally, only limited equipment is available to vessels using harbors, unlike ports, which have much heavier equipment such as cranes and gantries for loading and unloading of larger ships or container ships in the very largest ports. There are many different types of harbors and ports, often influenced by the history of the country or region where they are located and sometimes, depending

on their ownership, the type of business activity that occurs in them, how they are administered, and how they operate.

Types of Harbors and Ports

Natural harbors occur where shelter is provided by natural formations, such as a reef, a promontory of land, or some other naturally occurring barrier that protects ships or boats from wind or tide. These natural harbors may include almost landlocked areas where regular action is necessary to maintain access. If the natural protection is deemed insufficient to offer adequate protection from wind and water currents, particularly when weather conditions erode the level of natural protection over time, human-made structures such as breakwaters, jetties or sea walls can be built to provide additional protection. Human-made harbors also occur along rivers, with jetties or quays being built alongside or out from river banks to provide shelter for vessels; in some instances, the river channel may also be deepened and widened to allow access for vessels farther inland, giving access to road and rail transport links.

A port is a human-made location on a waterway—coast, river, or lake—where ships can be loaded or unloaded using equipment such as cranes or gantries, for example. Many ports are located in towns or cities that have grown in response to the transport of goods by sea over many centuries, although more recently, ports may start with identifying a suitable location and all other infrastructure and industrial and living spaces develop in response to that, creating modern port cities.

Ports require adequate road, rail, and inland waterway (river, canal) access to transport goods farther inland, and they can differ greatly in size and in the type of activities and vessels using them. The largest ports can extend for several miles along a riverfront and contain warehouses, storage facilities, processing facilities, freight transport links, cargo and passenger terminals, and a host of other facilities that create a highly important economic resource for the country in which they are located.

With the development of containerization and ever larger ships, new human-made harbors, ports, and terminals have been built in areas previously considered unsuitable. Reasons why an area may be deemed unsuitable include the lack of natural protection from wind, sea currents, or

adverse weather conditions at certain times of the year. Other reasons include limited access to existing harbor areas because of tidal conditions (ships only able to enter and exit at high tide), where a port is situated in an urban area with only limited room for expansion, or where a port is situated next to a fragile or protected environment, often factors for ports and harbors located along tidal estuaries.

New harbors, ports, and container terminals have been built in coastal areas in response to a lack of physical space available for expansion of existing ports (with ships being forced to queue to access the existing facilities) and in areas where the existing ports cannot accept the increasingly large ships being used to transport cargo and also passengers. Those factors may result in ships and cargo being transferred to other ports in a region with suitable facilities, with a consequent loss to the local (or national) economy. They are also being built by countries as free zones or bonded areas, where taxation rates are lower than in the rest of the country and customs regulations are less strict, giving an economic incentive for shipping and cargo companies to use the facilities offered by those ports and to develop new trading partnerships between countries.

Port Ownership and Administration

Port ownership traditionally falls into three categories: public sector, private sector, and a combination of both public and private. Those combined ports are further categorized as landlord ports, where the port is operated by a private company but the land and infrastructure is owned by the public body, which also regulates the port, and comprehensive ports, owned and operated by private companies but regulated by a public body or government. In comprehensive ports, regulatory functions such as traffic management, providing essential services, and setting regulations are the responsibility of a public body, but the land on which the port is built and operations that take place within the port are owned by a private company.

In addition to the general categories of port ownership described above, there are also other port types that may be specific to a country or region, or dependent on local circumstances such as national government regulation. Examples of other port types include trust ports, where independent

bodies have taken on all the port functions, set their own rules, and are run by independent board members on behalf of stakeholders; and charitable trusts, which depend on donations from the public to cover at least some of the costs of ensuring the port remains open.

Irrespective of port type, there are a number of functions that must be provided by and administered on behalf of the port. These are regulatory, landowner, and operational functions. Regulatory functions include enforcing laws and regulations, whether local, national or regional; providing vessel traffic management systems to ensure safe access and egress; licensing all activities that take place in the port; and safeguarding the interests of port users.

Landowner functions include but are not limited to maintaining and developing the land on which the port is built; maintaining infrastructure, including the water channel (to ensure the port remains accessible) and any protective measures (breakwaters, jetties); maintaining access road and rail links; building and maintaining office buildings, warehouses, and fixed equipment (including fixed cranes); and implementing policies to develop the port to meet the requirements of its users and owners.

Operator functions deal with the safe and appropriate transfer of goods (and passengers) from ship to shore, whether that is handled by the public sector agency or a private company.

In publicly owned ports, a Port Authority, generally established under national legislation, has responsibility to regulate all the activities of the port by ensuring that all appropriate laws are enforced (national or port specific, including labor laws and environmental regulations) and that there is adequate security in the port. The authority also administers all the land on which the port is located and all its assets, and also controls all port operations on behalf of the public. Port Authorities may also be responsible for ensuring that the port is adequately financed, that public safety is secured, and that adequate policing is in place. Public ports may be owned by a national Port Authority, usually part of a national government ministry (for example, a Ministry of Transport), or by a local municipality or council body.

In privately owned ports—single ports or large companies owning multiple ports within one

country or in several countries—all the functions of the port (regulation, land ownership, and operation) are owned by a private-sector company with the ultimate aim of making a profit for shareholders.

However, it should be noted that even in fully private ports, a Port Authority or other public body may still have some responsibility for ensuring that the private port operates within national or regional laws. This may include ensuring that the port adheres to legislation on working conditions for its employees, meets environmental standards set nationally or internationally, and maintains appropriate security and liaises with relevant agencies (police, border control, or security forces). In particular, ports are required to adhere to the requirements of the International Ship and Port Facility Security Code.

In addition to the administrative activities outlined above as being the responsibility of the Port Authority, there are a number of other administrative functions that are vital to ensure the safe and efficient running of a port or harbor. Those functions are generally managed by a Harbor Master (in small ports) or by administrative staff in the Harbor Master's Office in larger ports.

Those activities include handling day-to-day communication with port users, including ship's masters, shipping agents, cargo company agents, and external agencies such as waste companies, utilities (electricity, water, sewage, gas), and municipal council bodies, including traffic and road planners, building inspectors, and local police, for example.

They also have responsibility for collating statistics on numbers of ships visiting the port, types of cargos, maintaining weather and tidal data, ensuring that appropriate permits are held by companies and their workforce, and ensuring that relevant forms and guidance notes are made available to/adhered to by port users. In respect to inspections in ports, they need to provide a point of contact between inspection agencies and the ships or cargoes to be inspected, collating statistics for relevant agencies in that respect.

Port Operations

In addition to the administrative activities undertaken by the Port Authority and the Harbor Master's Office, there are a number of day-to-day

activities necessary to ensure that the port operates efficiently and effectively. Port operations can cover a range of services offered to ships using the port or to cargo operators on the land.

Services offered to ships include ensuring that they have somewhere to berth upon arrival in port, providing vessel traffic services such as radar, VHF radio communication, and other technology to track vessel movements in and around the port area, and making ship's masters aware of any restrictions for entry, including tidal conditions or local by-laws requiring ports to operate only during specific times. Other services offered to ships can include providing navigational aids such as charts, details of waypoints where the ship must change direction, and details of any wrecks or obstructions that need to be avoided.

Larger ports may also provide pilotage services where entry to the port is difficult due to local tidal conditions, hidden obstructions, or other hazards. In this case a pilot is transferred onboard ship and takes control of navigation to ensure its safe passage into the port area. Towing services, where small tugboats are used to pull (or push) larger vessels to a berth, may also be provided, and this is particularly useful when a ship entering the port is very large and unwieldy and takes a long time to come to a full stop under its own power.

Barges to remove some types of dry or liquid cargo can also be used, for example, if that cargo is being transferred to an inland waterway, so that it does not have to be landed on the quayside. Barges may also be used to remove waste oil, sewage, or garbage from a ship. Ports may also offer services for the delivery of fresh drinking water, food, or fuel and provide quayside connections to electrical power.

Services offered to cargo companies include provision of facilities to load/unload cargo (cranes, gantry cranes, fork-lifts, conveyor belts), to break cargo down into smaller loads (arriving cargo) or combine it into larger loads such as containers (departing cargo), and ensure that storage for solid or liquid cargo is available. Other services provided to cargo operators may include provision of areas within the port where cargo can be packed, sorted, and labeled; documents checked; and customs inspections carried out before the cargo is loaded on trucks or trains to be transported to its final destination.

Particularly in larger multiuse port, the more services the port can offer to shipping and cargo companies, the more likely it is that those companies will continue to do business with the port and it will remain economically viable. Ports must be responsive to the needs of user groups, while at the same time ensuring that they adhere to local and national regulations, such as those for security, border control, and customs, excise, environmental measures.

An efficient Harbor Master's Office, therefore, plays a vital role in both the administrative and operational aspects of the port, irrespective of the ownership of that port.

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See Also: Globalization; Harbor and Port Planning; Harbor and Port Security; Harbors, Design and Engineering of; Port Inspections.

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Hazardous Materials Transport

Although the transportation of hazardous materials (hazmat, or “dangerous goods” as they are often labeled outside the United States), may seem unnecessary, these substances include items necessary for contemporary lifestyles, including fuel, certain aerosols and adhesives, and even ethyl alcohol. Other hazmat includes biological or chemical substances used in academic and medical research. Myriad state, federal, and international agencies regulate the transportation of hazardous material to protect the safety of humans, property, and the environment because the cost of accidents is much higher when dangerous goods are involved. Though agencies and stakeholders have worked together to mitigate the dangers of hazmat transport, new controversies and debates continue to emerge both within the United States and abroad.

The U.S. Code of Federal Regulations defines hazardous materials as substances “determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated.” Explosives, ordnance, poison, flammable gases and solids, corroding agents, radioactive materials, oxidizers, ammunition, fireworks, combustible gases, as well as other regulated material such as those that could potentially damage the transport vehicle or other noxious, toxic, and irritating substances are included in the category because of their potential risk to health, safety, and property. These substances are categorized into nine classes: explosives, gases, flammable liquids, flammable solids, oxidizing substances/organic peroxides, poisonous (toxic) and infectious substances, radioactive material, corrosives, and miscellaneous dangerous goods.

Yearly, over 3 billion tons of hazmat, or 28 percent of the annual freight ton-miles, are transported in the United States by land, rail, sea, air, and 2.6 million miles of pipeline. Though estimates of the amount of hazmat transported outside the United States are not available, the total volume of hazmat movement internationally likely reflects a significantly larger amount. For example, the United Nations Conference on Trade and Development

estimates that almost 8,500 deadweight tons were carried by ship in 2010.

Incidents involving hazardous materials can be devastating to the well-being of individuals, property, and the environment. As delineated by the Code of Federal Regulations, reportable incidents include circumstances in which a person is killed or receives an injury requiring hospitalization as a result of contact with a hazardous material during the transportation process. Additionally, if the general public is evacuated, a major transportation facility or artery is closed, or an airline is rerouted from its operational flight pattern, reporting is required. Incidents also include fire, breakage, spillage, or suspected contamination involving radioactive material, infectious substances, or marine pollutants. The government requires detailed reporting following such incidents and administers a database to track their occurrence.

Since 2003, 162,449 incidents involving hazardous materials were reported in the United States, with a total of \$709,802,927 in damages, 2,723 injuries, and 131 deaths. Breaking these down by mode of transport: 14,145 involved air incidents, 140,332 highway, 7,311 railways, and 661 water. In 2012, 26 percent of incidents occurred during transit, 4 percent during in-transit storage, 20 percent during loading, and 50 percent during unloading.

Both federal and international agencies create and enforce legislation designed to minimize the frequency and the scope of accidents related to the transportation of hazardous materials. When manufacturers and transportation companies correctly observe the regulations, incidents are less likely to happen or be severe. Unfortunately, some companies choose economics over compliance, and some countries and regions have more political will and political capital than others.

Legislation in the United States

The Hazardous Material Transportation Act (HMTA) was passed in the United States in 1975 to regulate the transportation of hazardous materials. This legislation gave the secretary of transportation regulatory and enforcement authority for intrastate, interstate, and foreign shipments. The Toxic Substances Control Act of 1976 gave the Environmental Protection Agency (EPA) authority to oversee the production, use, and disposal of chemical substances. Section 8 of this act subjects commercial

manufacturers of chemicals to a number of recording and reporting requirements, such as health and safety studies and incidents of adverse reactions experienced by employees working with chemicals. The EPA also issues rules regarding acceptable limits of exhaust emissions by commercial vehicles.

The Resources Conservation and Recovery Act of 1976 specified instructions for using, treating, and tracking hazardous waste. The Hazardous Material Transportation Uniform Safety Act of 1990 aligned and clarified preexisting local, state, and federal laws relating to hazardous material transport. Most recently, because of the potential use of hazardous materials in acts of terrorism, the USA PATRIOT Act of 2001 forbade states from issuing hazmat licenses to individuals who have not been vetted by the Department of Transportation.

The Pipeline and Hazardous Materials Safety Administration (PHMSA), a Department of Transportation agency, has two divisions. The agency generates and enforces guidelines to ensure that transportation by land, sea, air, and pipeline is operated safely, reliably, and responsibly. The PHMSA operates five regional agencies that employ inspection and enforcement staff who ensure industry compliance with safety regulations through regular inspections and investigations of hazmat transport personnel, equipment, and procedures. The PHMSA also operates a pipeline safety training center in Oklahoma City, Oklahoma. In addition to inspection and enforcement, the agency provides new and revised hazmat standards to promote safety and minimize threat to health, property, and the environmental; it also conducts research to develop best practices and offers grants to states for their own pipeline safety programs. The PHMSA's directives apply not only to pipelines but also to any carriers of hazmat. Some of the standards specify the appropriate transportation containers for the given hazardous materials. Others outline the required manifest, marking, labeling, and placards demanded for proper hazardous material communication. The PHMSA delineates required training areas for hazmat employees who load or unload material, perform maintenance on or prepare shipping containers, operate vehicles transporting hazardous materials, or prepare hazardous materials for shipping. These employees must undergo general awareness training,

function-specific training, safety training, security training, and modal-specific requirements training, although the source and format of the training remains at the discretion of the employer.

The PHMSA works closely with other agencies, including the Federal Aviation Administration, the EPA, the U.S. Coast Guard, the Federal Railroad Administration, and the Federal Motor Carrier Safety Administration to coordinate safe hazmat transportation. Additionally, other federal agencies have jurisdiction over aspects of hazmat transport, including the EPA, and, in the case of worker health and safety, the Occupational Health and Safety Administration (OSHA).

International Regulations

Internationally, hazardous material transport is governed by two agreements: the International Civil Aviation Organization Technical Instructions for the Safe Transport of Dangerous Goods by Air (ICAO TI) and the International Maritime Dangerous Goods Code (IMDG Code). Additionally, the United Nations Committee and Subcommittee of Experts on the Transport of Dangerous Goods (UN COE and SCOE) meet twice yearly to discuss and ratify changes to the UN Model Regulations on the Transport of Dangerous Goods. While the UN Model Regulations are not legally binding, they do serve to inform the laws of member countries and help provide consistency and understanding among countries.

Directive 2008/68/EC of the European Parliament and of the Council of 24 September 2008 on the inland transport of dangerous goods governs hazardous material transportation within the European Union. Based on international agreements, the directive covers air, land, and sea shipments to reduce risks of accidents and threat to safety, health, and property damage. Many other countries have specific legislation governing hazmat transportation, and a substantial number of those countries provide reciprocity to shippers.

In Canada, the Transportation of Dangerous Goods Act, 1992, outlines requirements for the shipment of hazardous material within the country. Some provisions include, similar to those in the United States, labeling requirements, emergency planning and preparedness, and recordkeeping; the act authorizes the Minister of Transportation inspection and enforcement authority and outlines

penalties for infractions of the legislation. The ministry includes branches that develop training programs and operate a 24-hour emergency line, as well as branches that outline expectations for transportation and that provide inspection, investigation, and enforcement. Canada, Mexico, and the United States also work together to develop emergency response protocols for hazardous waste incidents.

China's State Administration of Work Safety (SAWS) released a decree, "Measures for the Administration of the Registration of Hazardous Substances," which became effective in 2012. These rules expand previous regulations and require domestic companies to provide extensive reporting of hazardous chemicals used as well as to disclose chemicals imported into China by foreign manufacturers. The reporting requires companies to disclose information on chemical classification, hazardous properties, usage, and emergency and safety procedures. Furthermore, the rules outline an expansion of China's Catalog of Hazardous Chemicals to include 7,000 to 10,000 substances.

The regulations and regulatory bodies represented by the United States, Canada, China, and the European Union are representative of the diverse laws governing hazmat transport, and the partnership among the United States and Canada, as well as participation in UN efforts, demonstrates positive progress toward protecting the safety of the world's population. However, the piecemeal regulations in a global economy often leave cracks whereby some countries and regions experience a disproportionate burden of the costs of hazardous materials. Hazardous waste is a case in point.

Hazardous Waste

Hazardous waste, or discarded materials harmful to human or environmental health when improperly managed, represents a concerning subcategory of hazardous material transport. Hazardous waste was not regulated in the United States until the 1970s when Congress passed a number of statutes to oversee the generation, transportation, and disposal of hazardous materials. The need for such legislation was underscored by high-profile incidents illustrating the devastating health and environmental effects of improper management and dumping of hazardous waste.

Developing and poor countries and regions are particularly vulnerable to devastating effects of

hazardous waste disposal. In 2006, for example, hundreds of tons of hazardous petrochemical waste were illegally dumped in Abidjan in west Africa's Côte d'Ivoire, resulting in 10 deaths and over 30,000 illnesses. The waste had originated in Amsterdam and traveled on a Panamanian-registered ship managed by Probo Koala, a Greek-managed firm, and chartered by the Dutch company, Trafigura, which claimed that tests on the waste conducted before the ship set sail indicated no toxic materials in the waste. Negotiations between Trafigura and the participants resulted in a 2007 settlement with the Côte d'Ivoire government for \$171 million (152 million euros), a 2009 settlement for no more than \$45 million (33 million euros) with the people made ill by the waste, and almost \$550,000 (400,000 euros) in fines to the Dutch government.

Contemporary Debates

Two current debates pitting environmentalists against the oil industry involve the transportation of hazardous materials. The proposed Keystone XL Pipeline, which would take oil extracted from Canadian tar sands across the U.S.–Canadian border in Montana and extend southward to the Gulf Coast in Texas. While many of the issues go beyond transportation of the oil, critics of the XL pipeline assert that future leaks are inevitable, especially since the diluted bitumen of the tar sands oil has more acidity, viscosity, and sulfur than conventional oil, although the Alberta, Canada, government disputes the claim that bitumen is riskier to transport. With this mix, current models of pipeline strength are misleading.

The high number of pipeline leaks—hundreds each year of varying severity—including the 2013 Exxon Pegasus pipeline leak of 5,000 barrels of crude oil in a residential neighborhood in Mayflower, Arkansas, and the 2010 Enbridge Oil Spill that released more than 10 million gallons of oil into the Kalamazoo River near Marshall, Michigan—indicate the inherent risk in these pipelines. That the Keystone I pipeline has already received orders of corrective action from the PHMSA in a short time of operation casts doubt on the state-of-the-art technology used to transport tar sands.

Hydraulic fracturing (or fracking), in which natural gas is extracted from shale mineral deposits, also generates emotional and contentious debates within many regions of the United States. While many of



A tug pushing a barge bursts into flames after striking an oil pipeline near Bayou Perot, south of New Orleans, Louisiana, March 13, 2013. There are hundreds of U.S. pipeline leaks every year.

the points are outside the domain of hazmat transportation, fracking does require the transport of chemicals to fracking sites as well as the movement of wastewater from the sites. Because of a provision in the Energy Safety Act of 2005, fracking chemicals are exempt from EPA regulation. Many fear the transport of these unreported chemicals poses significant health, safety, and environmental risks. In April 2013, a truck carrying fracking chemicals was turned away from a local radioactive, hazardous waste facility with a 96-microrem radiation level, 86 microrem above the facility's accepted range. This incident provided evidence for opponents of hydraulic fracking who fear that lax regulations will harm humans and the environment.

Critics assert that the safety regulations regarding hazardous material are not keeping pace with the technological advances and accompanying challenges. With increasing globalization and development, managing hazardous material within

and outside national borders should be a priority for decision makers. Businesses, too, can benefit from a standardized set of requirements. Additionally, because the air, water, and earth do not observe national boundaries, ensuring safe transportation of hazardous materials is critical to the overall health and safety of humans and the environment.

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See Also: Environmental Impacts; Environmental Justice; Environmental Protection Agency; Federal Highway Administration; Federal Motor Carrier Safety Administration; Federal Railroad Administration; Federal Transit Administration; Pipeline and Hazardous Materials Safety Administration; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Road Signage.

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Health Issues

The transportation decisions that are made on a daily basis determine far more than how quickly one may get from point A to point B; they can have social, environmental, and physical consequences that collectively influence the overall health of both individuals and communities. The health impact associated with an ever-increasing number of people traveling by automobile and a concomitant increase in annual vehicle miles traveled has reached epic proportions. Growing evidence is revealing the myriad adverse health consequences arising from such an auto-dominant landscape. Ranging from mild to severe, and even to death, the consequences of transportation decisions can impact both the individual as well as the collective. Furthermore, while the physical health of an individual is most closely associated with transportation choices one makes, there are potentially serious social and psychological repercussions as well. Though driving a personal automobile affords privacy and individual freedom, this transportation choice impacts not only the decision maker but a host of other individuals as well. Perhaps most obvious is the growing obesity epidemic, which stands as the fastest growing public health problem in the United States.

Automobile Travel

In the simplest of terms, research has shown that traveling in vehicles increases the odds of obesity whereas traveling by foot decreases the odds of obesity. Certainly the correlation between increasing vehicle miles traveled and increasing obesity is well documented. With the number of total vehicle miles traveled increasing by more than 200 billion miles during the first decade of the 21st century,

obesity rates in the United States soared. The adult obesity rate for men increased from 27.5 percent to 35.7 percent and from 33.4 percent to 35.8 percent for women. Currently, the national adult obesity rate stands at 35.7 percent and the child obesity rate at just under 17 percent. With more than 12 million children currently overweight, childhood diabetes is a serious and growing problem. While transportation choices can contribute to obesity, obesity can likewise affect transportation costs. Increased body weight necessitates more fuel be burned to transport the same number of travelers. For air travel, these fuel costs can run into the hundreds of millions of dollars each year. On the highway, it has been calculated that upward of 1 billion additional gallons of fuel are consumed annually due to overweight and obesity.

While obesity itself is a health concern, more problematic is its association with a host of additional diseases. Time spent in the automobile is shown to increase the likelihood not only of obesity but of heart attack, high blood pressure, and high cholesterol. Obesity has been likened to a "conveyor belt" that can lead individuals to experience a dangerous mix of obesity-related illnesses.

The Built Environment

A sedentary lifestyle where much time is spent in an automobile is a principal culprit in the obesity epidemic. Yet more than simply personal preference, use of the automobile has been necessitated by sprawling land use separated by rigid zoning codes and transportation planning that has set the automobile above all other forms of transport. As a result, people who live in neighborhoods with older or more "traditional" designs are noted for spending more time walking and in total physical activity than those who live in newer, more suburban landscapes. The post-World War II era represents a marked shift in land use and transportation planning policies, with the gridded streetscape replaced by cul-de-sacs and mixed land use replaced by single-use zoning. The sprawling design has rendered this new suburban landscape nearly unwalkable and necessitates use of the automobile for virtually all trips. As the suburban landscape has expanded, the percentage of children walking or bicycling to school has declined. Without question, the built environment has a significant impact on human health and behavior.

Pollution

Furthermore, per capita vehicle miles of travel also positively correlate with emissions of nitrogen oxide (NO_x) and volatile organic compounds (VOCs). In sunlight, these pollutants react to form ground-level ozone, which can contribute to shortness of breath and even asthma. Not surprisingly, sprawling, car-dominated communities are associated with significantly higher emissions of NO_x and VOCs than the higher density, more traditional neighborhoods.

These air pollutants are also linked to many other health concerns, including respiratory morbidity and mortality, cardiovascular disease, lung cancer risk, birth defects, and eye irritation. With the automobile as a way of life, motor vehicle emissions have become the largest and fastest-growing source of air pollution and greenhouse gases. Moreover, with highways typically routed through low-income neighborhoods, a disproportionate share of air pollution burdens the health of the poor and people of color.

Noise from highways and other transport sources, including air travel, is increasingly being recognized as an environmental health issue. Described as unwanted sound, noise can affect cognitive performance, as well as mental health, physiological function, and even hypertension and heart disease. Without question, transportation-related noise concerns are affecting the health and overall quality of life of a large and growing proportion of the population.

Accidents

Transportation systems are an integral part of the built environment but are fraught with danger. Not only associated with secondary or indirect health concerns, transportation-related accidents can directly lead to serious injury and even death. Motor vehicle crashes are responsible for more than 40,000 deaths and upward of 3 million injuries per year in the United States alone. The leading cause of death for U.S. teenagers, motor vehicle crashes account for more than one in three deaths in this age group. In recent years, upward of 3,000 teens have been killed and more than 350,000 have been brought to emergency rooms for injuries resulting from motor vehicle crashes.

An increasing concern in driving fatality is the rise of distracted driving. Contributors to distracted

driving include use of a computer, cell phone, or onboard or heads-up navigation systems. In the United States, upward of one in six fatal collisions is the result of a driver being distracted when operating a vehicle. By far the greatest danger of distracted driving results from texting while driving. Studies have demonstrated that drivers who text are 23 times more likely to crash as nondistracted drivers. Thousands of additional road fatalities in recent years have been attributed to rapid increases in texting volumes.

Alternative Transportation

Loss of life is unquestionably the worst outcome and greatest concern; however, the economic cost of traffic crashes is also not insignificant. Reaching more than \$150 billion annually in property damage and injuries, alleviating this economic burden is another motivating factor to improving transportation safety. In response, there have been increasing calls regarding the need to develop alternative transportation opportunities—including walking, bicycling, and mass transit—through a holistic approach to transportation management. More transportation options can help relieve traffic congestion, reduce accidents, and improve environmental health concerns associated with transportation.

In recent decades, there has been a growing recognition that pedestrian-oriented development can contribute to the mental and physical health of an individual. As a result, new communities are being designed and existing communities retrofitted so that they emulate traditional, walkable neighborhoods. This design promotes both safety and transportation equity as well. In a country with an aging population, a near singular dependence on the automobile will no longer be sufficient. As a result, transportation options that afford freedom while addressing critical health and safety concerns are now being implemented.

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See Also: Automobile Accidents and Prevention; Environmental Impacts; Environmental Justice; National Highway Traffic Safety Administration; Transportation and the Disadvantaged; Urban Sprawl Versus Compact Development.

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Heavy Rail Transit

Heavy rail is a significant component in the transportation network of the United States. It consists of electrically propelled cars that operate in a tunnel (subway), on elevated tracks, or on a separated right-of-way. The trains of four to 10 cars, with average overall speeds from 25 to 40 miles per hour, provide the highest passenger capacity of any mode of urban rail transportation, but it is also the most expensive. Heavy rail systems are generally powered by a high-voltage third rail. The necessity of protecting people and vehicles from this voltage mandates that the rail system be fully separated. The separation is the source of heavy rail's high performance and its high capital costs.

Heavy rail is the dominant transit system in major urban centers in the United States, with some systems built more than a century ago and others dating from the last half of the 20th century. Since the 1980s light rail systems have substantially outnumbered heavy rail systems, largely because the costs of heavy rail can range from \$100 million to over \$1 billion per mile.

The Historic Systems

The oldest heavy rail systems in the United States were built before World War II, some of them as early as the 19th century. These systems were

generally built by private companies and later taken over by local governments dedicated to keeping the systems in operation. The best known of the early systems is the New York City Subway.

A subway system of nine lines serving 27 stations opened for business at 7 P.M. on October 27, 1904. The receipts for the first day of operations totaled \$5,594.05, representing 111,881 nickel fares. The entire sum was donated to hospitals in the city. Calls for expansion were almost immediate, and in 1913 the city signed contracts for the construction of another 123 miles, using both public and private capital.

The first passengers rode Chicago's famous L on June 6, 1892, when 30 people rode the Chicago and South Side Transit Railroad from 39th Street to the Congress Street Terminal. Extension came quickly in Chicago as well. By 1893, when the World's Columbian Exposition opened in Chicago, service ran to 63rd Street and Jackson Park.

In 1897 Frank J. Sprague invented a multiunit train control system for use on the L that allowed multiple railcars to be fitted with motors and eliminated the need for locomotive-hauled trains in rapid transit service. Boston (1897) and Philadelphia (1936) also had systems in operation during the first decade of heavy rail use in the United States.

These early systems were constructed with stations placed close together in order to reach more pedestrian patrons. Speeds were slower, and cars were shorter, designed for the tight corners characteristic of the urban areas they served. On February 4, 1952, nearly 20 years after Philadelphia's heavy rail line began operation, the Cleveland Transit System broke ground for a new heavy rail system. Service began on March 15, 1955. The Cleveland system was an anomaly. The period after World War II saw the automobile become the major mode of transportation.

Although some of the older heavy rail lines continued to expand, mass transit generally was faring poorly. A subway planned in Cincinnati had its right-of-way commandeered for freeway construction. It would take a shift in federal policy before a new kind of heavy rail system would draw other cities into heavy rail construction.

The Modern Systems

Only 3.9 percent of Americans were using any form of mass transit to get to work in 1960, and

one-fourth of those were in New York City. In 1964, President Lyndon Johnson signed the Urban Mass Transportation Act, which authorized \$375 million in aid for the capital costs of transit projects, with each federal dollar to be matched with one local dollar. Presidents during the next six administrations stressed the importance of mass transit in modern America.

In 1974, President Gerald Ford signed the National Mass Transportation Assistance Act, which distributed federal funds by formula for the first time in order to ensure that funding was available to help meet the transit needs of all of America's urban areas. President Ronald Reagan signed the Surface Transportation Assistance Act of 1982, which provided for a portion of the federal motor fuel tax to be used for public transportation investments. The amount of tax collected was increased during the George H. W. Bush and the first Bill Clinton administrations.

The first system to be built after the increased availability of federal funds was the Bay Area Rapid Transit (BART) system serving the San Francisco Bay Area, which opened to passenger service in 1972. The \$315 million in federal capital grants BART received helped make it the system it was, but federal aid made up only 20 percent of the total \$1.6 billion invested in the system. The heavy rail systems built after BART and additions and modernizations to older systems in Boston, Cleveland, New York, and Philadelphia received 80 percent of their funding from federal sources.

The systems that followed were much more heavily dependent upon federal investment. The Washington, D.C., Metrorail opened in 1976, followed by the Metropolitan Atlanta Rapid Transit Authority (MARTA) in 1979. The size of new systems decreased in the 1980s as the costs of both construction and operation increased. MARTA is 48 miles long; Baltimore's Metro, built in 1983, is 16 miles long.

Miami's Metrorail, which opened in 1984, is 24.4 miles. Unlike the earlier systems, the modern systems are designed to give automobile drivers an alternative. The stations are farther apart, the speeds are greater, and parking lots at outlying stations are standard. The Los Angeles Metro Rail is the only heavy rail system constructed in the 1990s. The Tren Urbano (Urban Train) in San Juan, Puerto Rico, began service in 2004.

Heavy Rail in the Twenty-First Century

Heavy rail continues to carry more passengers than light rail. In 2012, according to the annual report of the American Public Transportation Association, 3,648,329 unlinked passenger trips were made on heavy rail lines, many times more than the 488,504 trips on light rail lines. But nearly 90 percent of the heavy rail trips were made by passengers on the five busiest systems: New York; Washington, D.C.; Chicago; Boston; and San Francisco. More than 60 percent, or nearly 2.5 million trips, were made by New York City passengers. Six of the 15 systems reported fewer than 20,000 passenger trips for 2012.

Although existing heavy rail systems continue to construct extensions, they do so at enormous costs. The BART San Jose extension, scheduled to be completed in 2014, carries an estimated cost of \$251 million per mile. Costs are even higher for the Washington Metro extension to Dulles Airport, the second stage of which is supposed to be completed in 2016—at an estimated \$268 million per mile.

Most staggering is the \$2.1 billion per mile for the Second Avenue Subway in New York, also scheduled for a 2016 completion date. These construction costs added to maintenance and operating costs, which are also more substantial for heavy rail, have led some experts to predict that the day of heavy rail systems is ending except for the nation's most densely populated cities.

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See Also: American Public Transportation Association; Light Rail Transit; Railroads, Passenger; Subways/Elevated Trains; Surface Transportation Assistance Acts of 1978 and 1982.

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Helicopters

Helicopters are the most common type of rotary-wing aircraft, which generate lift through the revolution of wings (rotor blades) around a mast. In the case of helicopters, these rotors are driven by one or more engines throughout the flight, and the rotors also provide multidirectional thrust. Rotary-wing aircraft, though limited in their passenger and freight capacity as a result of size limitations, have a number of advantages over airplanes.

For instance, because they take off and land vertically, they require less horizontal space in which to do so and can do so more quickly. Adjusting the direction of the rotors allows helicopters to quickly maneuver forward, backward, or sideways, as well as to hover. This combination, which allows them to operate from rooftop helipads, has led to their use in emergency services. Other factors, such as their maneuverability and their ability to fly safely at low altitudes, have made them practical for disaster response, police use, and search and rescue operations.

Origins

Helicopters are among the earliest type of flying vehicle that humans attempted to construct. Rotary-wing toys have been successfully flown since ancient times, and the seeds of some plants, including the tipu tree, maple tree, box elder tree, and gyrocarpus nut, have distinctive wings that cause them to rotate in the air in a manner similar to helicopters, which inspired many early designs long before the physics of flight were well understood. The most famous designs are those of Leonardo da Vinci, the Renaissance man who in the 15th century designed a rotary-wing aircraft whose mechanics were inspired by the screw, though he seems never to have constructed his flying machine.

The word *helicopter* was coined in the 19th century, when Industrial Revolution engineers experimented with various forms of heavier-than-air vertical flight at a time when lighter-than-air flight in the form of hot air balloons had captured the popular imagination. Successful helicopter flights were made in the first decade of the 20th century, around the same time as the first successful airplane flights. Further developments were slower to come, and the helicopter industry did not really begin until the late 1930s. Both Germany and the United

States developed helicopters for military use during World War II, with the latter effort leading to the Sikorsky R-4, the first mass-produced helicopter, released in 1942.

Innovations

The R-4 used the rotor configuration that has become standard in the industry, consisting of a single, centrally positioned, lifting rotor (with three rotor blades) and a vertical tail rotor. Igor Sikorsky was the first to successfully use a tail rotor for antitorque, which has become part of the standard design for single-rotor helicopters. The tail rotor stabilizes the helicopter by generating thrust in the same direction as the rotation of the lifting rotor, which counters the torque created by the lifting rotor. The amount of antitorque created is controlled by pedals in the pilot's seat, which adjust the pitch of the tail rotor.

The tail rotor is one of the defining features of the modern helicopter and is important enough to safe flight that in most jurisdictions, and in the procedures followed by most aviation companies, it is one of the life-limited parts of the aircraft. Life-limited parts are routinely replaced with new parts after a predetermined number of flight hours, rather than relying on the subjective criteria of an inspection. Tail rotors, as well as elements of the drive system, are also inspected through fluorescent penetrant inspection (FPI) between replacement cycles. FPI is a chemical method of revealing—through use of a fluorescent dye—defects that would otherwise not be apparent in a naked-eye inspection.

The inspections require a skilled inspector to perform them, but apart from the labor cost they are cheap, fast, and effective. Helicopters are also generally equipped with a vertical stabilizer—a fin that helps keep the helicopter from rotating perpendicular to the rotors.

Some helicopter designs incorporate alternatives to the tail rotor, with some other means of countering the torque of the lifting rotor's rotation. Tipjets, for instance, mount the engine on the tips of the rotor blades instead of inside the helicopter's chassis and spin the rotor with small powerful nozzles. The jets may be afterburners, ramjets, or may use compressed air. By using tipjets to rotate the rotors, no torque is created, and no antitorque is required.

The principal difference between the early Sikorsky helicopters and modern helicopters is the engine type. Helicopters took longer to develop than airplanes because of their minimum engine requirements and the difficulty of generating enough power to create lift without adding too much weight to sustain flight. Sikorsky was the first to surmount the hurdle, using a piston engine design that is still used for some smaller helicopters. But in the 1950s an improvement was made, introducing a turboshaft engine that generated more power with less weight. Like a turbojet engine, a turboshaft is a gas turbine, but instead of producing thrust, it produces shaft power. Most helicopters today use lightweight turboshaft engines, which allow for faster flight and larger craft.

Regulations

While there are other aircraft capable of vertical takeoff and landing, helicopters are unique in their ability to hover for long periods of time. They can also maneuver and remain aloft at low airspeeds, which an airplane, for instance, cannot do. Helicopters can maneuver safely in areas airplanes are unable to access because of congestion or other dangers, and many of the uses to which helicopters are put take advantage of this, though it also poses regulatory questions. Because helicopters do not need as large a space for takeoff and landing as airplanes and are not as loud, Federal Aviation Administration (FAA) regulations concerning them are not as strict. However, businesses, residences, or medical facilities wishing to deploy helicopters from their property not only need the relevant licenses and permits but also need to ensure that their neighborhood is zoned for a helipad.

In many cases, specific routes are required of helicopter pilots (though requirements of this sort are often lifted in the case of search and rescue operations and other crisis response). For instance, the FAA and the New York State Department of Transportation maintain the New York Helicopter Route Chart, which consists of both suggested and mandatory helicopter routes, directing helicopter traffic along specific routes for the purposes of traffic management and public safety. Noise pollution is one of the leading concerns in helicopter traffic management.

There are also specific regulations pertaining to helicopter traffic at airports. At airports without

towers, helicopters are required to avoid airplane traffic and, like airplane pilots, they must announce their positions over radio using a common frequency. Because of their greater maneuverability and lesser runway needs, helicopter pilots are expected to pay attention to nearby airplanes and take pains to avoid them. At tower-controlled airports, air traffic controllers direct helicopter traffic, which may or may not be segregated from airplane traffic. While in flight, helicopters are subject to reduced visibility requirements compared to airplanes because they are more maneuverable.

Use

Helicopters are used for recreational flight and tourism, because their ability to fly low to the ground, hover, and fly slowly is well suited to sightseeing; for aerial observation, including surveillance and mapping, though smaller automated rotary-wing craft and drones are often used for this purpose today; for search and rescue operations; for fast transport in the military, during evacuations, and transfer of medical patients; for cargo transport; in firefighting, to deploy water and fire-extinguishing substances; and in construction. Aerial cranes are helicopters that carry loads via slings or cables, and they are the ideal means, in some cases the only practical means, of installing certain types of equipment on high places, such as rooftop equipment or mountain-top radio towers.

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See Also: Air Traffic Control; Air Travel; Evacuation Planning; Helicopters, Emergency Response and Law Enforcement.

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Helicopters, Emergency Response and Law Enforcement

As more dramatic examples of what can occur during otherwise routine workdays for emergency response helicopter crews, New York Police Department (NYPD) helicopters plucked passengers from the wing of Captain Chesley Sullenberger's downed U.S. Airways flight 1549 in the Hudson River on January 15, 2009, and a Los Angeles Police Department (LAPD) helicopter found lost hiker Danny Kim in the Angeles National Forest on January 13, 2013.

In the 2010s, approximately 800 law enforcement air support units operated in the United States and a comparable number in Europe, Asia, Australia, and other parts of the world. In the United States, local, state, and federal agencies use helicopters to support their missions, ranging from one helicopter in a local police department to the large helicopter fleets of the Federal Bureau of Investigation, the Drug Enforcement Administration, and the U.S. Customs Agency. Law enforcement air support units have grown so numerous that the Federal Aviation Administration (FAA), which has the responsibility of overseeing them, is sometimes hard-pressed to keep pace with its regulatory and enforcement responsibilities.

Even small states like Delaware have law enforcement rescue units; the Delaware State Police Aviation Unit performed approximately 2,000 missions in 2011. In May 2011, the Delaware unit answered an emergency call from the captain of the Greek tanker *Cosmic*, who reported that one of his crew members had fallen 20 feet and injured his head. The Delaware Air Rescue Team helped package the crew member, hoist him into the helicopter, and transport him to a hospital on shore.

Special Rescue Qualifications

Helicopters bring unique operating characteristics to law enforcement air support units. The helicopter's ability to take off and land vertically and its hovering capability give it a major advantage over fixed-wing aircraft. Because helicopters can hover, they can reach crevices and other places that are inaccessible to fixed-wing aircraft and other machines to rescue trapped people. Often helicopters come

equipped with winches that enable them to lower materials, move heavy objects, or lift injured people to safety. Technological advances, including no-tail rotors, night surveillance equipment, and quieter engines and parts, make the helicopter state-of-the-art effective.

Helicopters in law enforcement units rescue hikers stranded on mountains and in other places. The Phoenix Fire Department (Arizona) used a helicopter to lift a dying hiker off Camelback Mountain. They lowered a basket on a rope from the helicopter, secured the patient in the basket, and began to hoist him up to the helicopter. The basket containing the stricken hiker dangled from a rope high off the ground, and as the helicopter crew began to raise the basket, the rotor blades started spinning so quickly that the crew had to lower the basket and bring it back up again. The helicopter crew said that the patient, who fully recovered, would have died if the Police Department had not used its helicopter.

New York, Los Angeles, and Chicago Fleets

The NYPD's Aviation Division operates a coordinated air-sea rescue program complete with helicopters and scuba divers based at Floyd Bennett Field in Brooklyn. In 1929, the NYPD founded an air rescue unit stocked with fixed-wing aircraft, but by 1948, the department routinely used helicopters instead of fixed-wing aircraft because they were so easy to maneuver in the sky. NYPD helicopters have rescued civilians trapped on the ice, spotted fires, chased speeding automobiles, and spotlighted cars from the air for ground patrol officers to capture.

During the January 2009 rescue of the passengers on U.S. Airways Flight 1549 from the Hudson River, NYPD air-sea rescue units pulled two survivors from the icy river and treated them for hypothermia. When Hurricane Sandy struck in October 2012, the NYPD helicopter No. 23 rescued five adults and one child, all Staten Island residents, trapped on rooftops by rising waters. (Helicopter No. 23 was named for the 23 NYPD officers who died in the Twin Towers on September 11, 2001.)

After the NYPD pioneered the first law enforcement rescue unit in 1929, word of the helicopter's utility and maneuverability quickly spread from the NYPD across the country. Los Angeles County in California bought its first helicopter in 1956. Los Angeles County used its first helicopter to

help patrol traffic on the city's freeways, but the county enlarged the helicopter's role during the 1965 Watts riots when they used it to spot problems and direct policemen to the trouble spots. In the 21st century, the LAPD maintains the largest police aviation unit in the United States, operating a fleet of 17 helicopters and a King Air 200 out of Hooper Memorial Heliport in downtown Los Angeles. LAPD police helicopters are used to rescue stranded hikers, transport people needing medical attention to hospitals, and pull people from burning buildings.

The Chicago Police Department's Marine and Helicopter Unit features two helicopters, technically trained personnel, and specialized equipment to conduct rescue missions. Its helicopters routinely rescue boaters and swimmers from Lake Michigan.

Regulating Helicopters and Their Units

More helicopter units in the air means more potential for accidents and more conflicts between overlapping law enforcement units and between private helicopter companies and law enforcement agency fleets. Established in 1972, Helicopter Emergency Medical Service (HEMS), consisting of for-profit and nonprofit agencies, grew 130 percent between 1995 and 2008. Accidents and competition between law enforcement agencies and HEMS also have multiplied, with media stories recording "patient wars" between police and other medical transport helicopters.

The FAA has broad authority and responsibility to regulate aircraft operations, to monitor the use of navigable airspace, and to establish safety standards for and regulate the certification of air personnel, aircraft, and air carriers. The agency establishes safe altitudes to protect individuals and property on the ground, and attempts to temper excessive aircraft noise. It also addresses helicopter safety issues like the impact of weather on takeoffs and landings, night operations, and controlled flight into terrain incidents.

From 2011 to 2012, the FAA documented problems with the Port Authority of New York and New Jersey's operation of airports, including JFK, La Guardia, and Newark airports. The FAA's report cited the Port Authority for failure to instruct its police departments to oversee its rescue and firefighting air units. According to the FAA, every day during 2011 and the first half of 2012, JFK failed to



A low-flying U.S. Customs and Border Protection UH-60 Blackhawk helicopter bears down on two trucks during operations near an air strip in the U.S. southwest in 2008.

ensure that rescue and firefighting personnel were adequately trained. The FAA levied a \$3.5 million fine against the Port Authority and, in a 25-page settlement with the FAA, the Port Authority agreed to create a separate chain of command and training for rescue personnel and firefighters. Whether fire and police department helicopter units should operate separately or cooperate or combine operations is a hotly contested issue and one that will endure as air space becomes more crowded and operating costs continue to rise.

The effectiveness of the FAA and its safety regulations can be political and divisive issues. The National Transportation Safety Board (NTSB) is an independent federal agency that is responsible for investigating transportation accidents, promoting transportation safety, and reviewing enforcement actions involving FAA aviation and mariner

certificates and civil penalty actions. Two different regulatory agencies, each monitoring the other, sometimes cause confusion, political maneuvering, and in-fighting.

Future Large-Scale Rooftop Rescues?

Regulatory agencies like the FAA are also compelled to deal with technological changes in equipment, but many law enforcement agencies are resistant to changes in equipment and policies. In 1980, when a fire broke out at the 26-story MGM Grand Hotel in Las Vegas, police and helicopter pilots spotted the smoke first and sent out a radio alert. Thirty public and private helicopters mobilized to move 300 people from the roof and, with the help of the police keeping order, they succeeded. Eighty-four people died in the MGM Grand fire, but the people on the roof survived.

Thirteen years later, a catastrophic event revived the rooftop rescue issue. Shortly after 9/11, a *Wall Street Journal* story recalled that on February 26, 1993, a terrorist bomb exploded in the basement garage of the North Tower of the World Trade Center, funneling thick smoke up through the stairwells. Police rescue helicopter pilot Greg Semendinger lowered two men on a rope to the roof and they cut down antennas to clear a landing area for the helicopters. The helicopters rescued 28 people from the roof. The story pointed out that after the 1993 bombing, the Port Authority of New York and New Jersey, owners of the World Trade Center, and the fire department did not plan for future helicopter rescues.

On 9/11 two police rescue helicopters hovered a few hundred feet away from hundreds of workers trapped on the floors above the fire in the North Tower of the World Trade Center. Greg Semendinger again found himself planning a helicopter rescue. One of the helicopters carried a 250-foot hoist that could transport as many as 10 survivors at once, and its three-man crew had special training for rooftop rescues. The police helicopter pilots swooped in, but none of the survivors reached the roof because of locked doors and a predetermined evacuation plan.

The controversy about stairwells, locked roof doors, and the New York Police and Fire Departments' disagreement about fire rescue methods still continues. The New York Fire Department's opposition to helicopter rescues coincides with

the American mainstream approach. Fire experts around the country concluded that evacuating people is the best course of action when fires break out in skyscrapers and it is essential to send people down the stairs, not up to the roof. They point out that smoke and flames tend to rise, and people can get trapped on roofs if weather or smoke conditions make it impossible for a helicopter to approach.

Los Angeles is one of the few major American cities that defies conventional wisdom and requires high-rise buildings to plan for aerial rescues by mandating developers to build helipads on all buildings more than 75 feet tall, or about seven stories. The Los Angeles Fire Department used helicopters to rescue people from the roof of the 62-story First Interstate Bank Building during the fire of May 4–5, 1988, after which the LAPD embraced helicopters and their fire rescue possibilities. The Los Angeles Fire Department eventually established its own six-helicopter rescue wing.

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See Also: Aircraft Design; Aircraft Propulsion, New Technologies of; Aviation, Private; Emergency Transportation Planning and Operations; Emergency Vehicles; Evacuation Planning; Helicopters.

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High Occupancy Toll Lanes

High occupancy toll (HOT) lanes are road traffic management schemes whereby single occupancy vehicles are allowed to use high occupancy vehicle (HOV) lanes through the payment of a toll. Interest in HOT lanes has grown in recent years, and

projects have been implemented in several cities in the United States. The use of HOT lanes has potential advantages in terms of reduced congestion and pollution. However, there are doubts regarding the financial viability of the schemes, as demand for the use of HOT lanes may be insufficient to generate the revenue required to finance the costs of implementation and operation. Critics have also questioned the equity effects of the projects, arguing that they benefit road users who have greater ability to pay.

High occupancy vehicle (HOV) lanes are usually open to vehicles with a minimum of two or three passengers. These lanes allow faster speeds than other lanes, reducing congestion and promoting carpooling. However, the lanes tend to be underutilized and as such they represent an inefficient use of road capacity. Public perception of this inefficiency also reduces the social and political feasibility of the implementation of new HOV lanes. High occupancy toll (HOT) lanes address these problems by extending the use of HOV lanes to vehicles with one or two occupants in exchange for a toll. The scheme is also known as managed lanes or express toll lanes. The last concept is also used to describe HOT lanes where all vehicles, including high occupancy vehicles, are required to pay a toll.

The toll is collected through electronic toll collection systems, charging automatically the owners of the vehicles registered in the system without requiring them to stop when entering the lane. The toll is usually variable based on congestion levels, either set at certain times of the day or adjusted in real-time based on traffic levels. In some cases, the use of the HOT lanes is free for all vehicles during off-peak periods. The use of these variable pricing methods facilitates the management of demand for the use of HOT lanes, ensuring an efficient use of the total road capacity throughout the day, while preventing congestion in the HOT lanes.

HOT lanes are typically implemented in large urban areas and address specifically the accessibility needs of commuters, aiming at a reduction of time in the journey to work. These lanes have fewer ingress and egress points than general purpose lanes, providing fast access from a selected number of residential areas to the central business district (CBD) or other areas with high density of employment or services.

The QuickRide scheme in Houston, Texas, was one of the first HOT schemes, allowing vehicles

with two passengers to use HOV lanes during the peak period in the Katy Freeway. The scheme was introduced in 1998 and has since been expanded to other freeways. Similar projects have been implemented in other urban areas in the United States, with special incidence in California. These projects are usually limited to a selected number of roads in each city. However, in the San Francisco Bay Area an entire network of HOT lanes is currently being developed. This network will be 500 miles long upon completion in 2035.

Benefits and Drawbacks

The introduction of HOT lanes has a potential positive effect on urban accessibility, as the reallocation of traffic reduces congestion in general purpose lanes and allows for higher average speeds in those lanes without affecting speeds in HOT lanes. The implementation of HOT lanes also has advantages in terms of environmental quality, as the vehicle idling time on congested roads tends to be related to higher fuel consumption and higher emissions of local and global air pollutants. However, this positive effect may be canceled if many users respond to the implementation of the scheme by shifting from carpooling to driving alone in HOT lanes, thus increasing traffic levels. In the cases where HOT lanes are newly built, there is also a negative environmental effect linked to the use of extra land or the construction of elevated sections.

The advantages of HOT lanes in terms of reduced congestion may not be fully realized if the scheme fails to attract enough demand. Although the use of the HOV lanes tends to increase after the introduction of the scheme, it has remained in many cases significantly below the targets defined by the operating agencies. This means that road capacity in HOT lanes stays underutilized and congestion in the general purpose lanes is still above the optimum.

The problem arises because road users can opt between the use of general purpose lanes and carpooling or driving in single-occupancy vehicles in the HOT lanes. The choice between these options depends on the toll charged and also on the characteristics of the trip, such as length, time of day, purpose, safety, and convenience. There is also an element of uncertainty affecting choice in the cases where the toll is determined in real-time, as users cannot know in advance the price they will pay

for the use of the lanes. Research shows that HOT lanes are mainly used by drivers traveling longer distances. However, most drivers seem to use the lanes infrequently, for example, when traveling to places where they do not go on a regular basis. A survey of the use of the QuickRide facility in Houston showed that users of the system make less than 2.5 trips per month in the HOT lanes.

While HOT lanes are an additional source of revenue for transportation agencies, there are doubts regarding their long-term financial viability. The cost of implementation of the scheme is variable, depending on whether it involves the construction of new lanes or only the adaptation of existing HOV lanes. However, in the cases where demand is low, the system may not be financially sustainable if revenues are insufficient to cover operating costs.

There is also a high degree of monthly and annual variability in revenue, depending on macroeconomic variables (such as employment and income) and on environmental conditions (such as weather). A variety of funding and operating systems have been adopted, usually involving a mix of public and private capital. In the cases where the system is not financially sustainable, the system can be adapted by charging all users of the lane, including single-occupancy vehicles.

As with other road pricing schemes, there is also a social equity dimension to the effects of HOT lanes. Analysis of the socioeconomic characteristics of users of HOT lanes usually shows that individuals who are younger, single, and have lower income, lower education levels, and belong to racial minorities are less likely to use the system. Critics argue that because these groups have lower ability to pay to use the lanes, they are not provided with a choice to avoid congestion and are therefore at a disadvantage compared to other road users.

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See Also: High Occupancy Vehicle Lanes; Road Pricing Schemes, U.S. and International; Single-Occupant Vehicle Trips; Traffic Control Devices.

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High Occupancy Vehicle Lanes

High occupancy vehicle lanes (often called HOV, diamond, or carpool lanes) are special lanes that give priority to high occupancy vehicles such as carpools and buses. HOV lanes are used to combat congestion, increase person throughput, improve air quality, and reduce fuel usage by encouraging drivers to carpool or use transit. Most HOV lanes are found in the United States and Canada, although Australia, New Zealand, and a few European countries have experimented with HOV lanes.

Classification of HOVs and HOV Lanes

The number of passengers necessary to be classified as a high occupancy vehicle (HOV) varies among and even within cities. At minimum, a high occupancy vehicle must have two or more passengers per vehicle; this is called an HOV2+ requirement. Other areas have three or more passengers per vehicle, or HOV3+ requirements. Finally, some areas restrict HOV lanes to buses and emergency vehicles only. Exceptions to these policies vary: motorcycles, two-seater vehicles, and taxis are often exempt, for example.

HOV lanes may have different definitions of HOVs, depending on the time of day. For instance, a lane may be HOV3+ during the peak period but HOV2+ or open to all vehicles during nonpeak periods. HOV lanes may also adapt to traffic patterns by being reversible lanes. Reversible lanes allow HOVs into the city in the morning but reverse directions

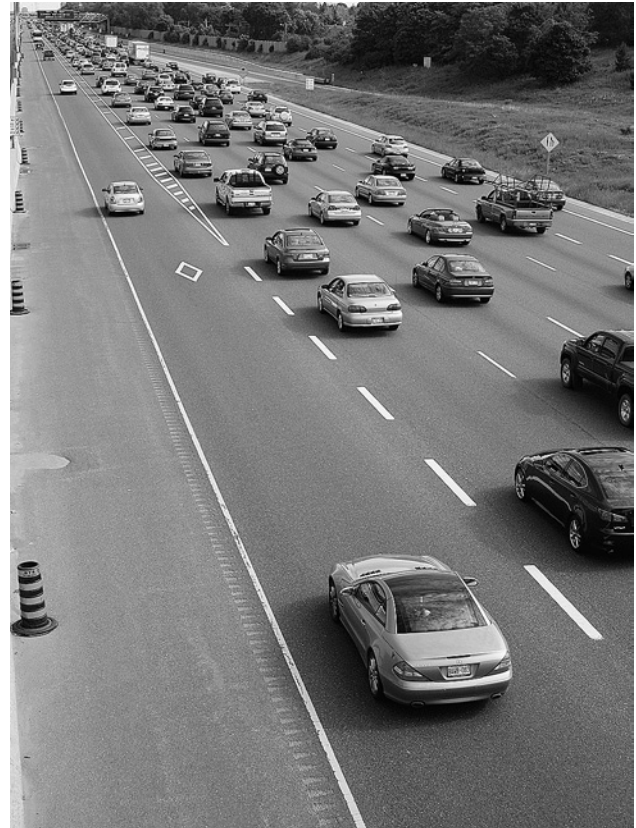
to allow HOVs out of the city during the evening rush. Reversible lanes may be exclusive HOV facilities that are physically separated from the general-purpose lanes or they may be contraflow lanes that are generally found in the median of the road and use lanes in the off-peak direction for HOVs traveling in the peak direction.

A dramatic example of contraflow lanes are the “zip lanes” that use special trucks to move a flexible barrier from one side of the road to the other in order to make space for HOVs in each direction. Zip HOV lanes can be found in Boston and Honolulu. Concurrent HOV lanes are lanes that are not physically separated from the general-purpose lane. They usually involve signage or paint striping to communicate they are for HOVs only. Some HOV facilities are simply on-ramps for congested areas or on-ramps with signal priority for HOVs. New HOV lanes may be added to the highway by converting a general-purpose lane or building a new additional lane. The distinction between a converted lane and an additional lane is important for understanding the impacts of HOV lanes because an additional lane adds to the traffic capacity of a road network and is more likely to create an increase in vehicle miles traveled (VMT).

Effectiveness of HOV Lanes

No consensus exists on the success of HOV lanes or even what criteria should be used to evaluate success. Many studies look at traffic-oriented outcomes, such as average vehicle occupancy (AVO), person-hours of travel, variability in person-hours traveled, the number or percentage of people carpooling, person-miles traveled, parking revenues, vehicle miles traveled, and travel costs, while other studies use economic welfare criteria such as compensating and equivalent variation and/or consumer surplus. Yet another aim of HOV lanes is to reduce air pollution and fuel usage. This may be accomplished by reducing the number of vehicles, by maintaining the number of vehicles but reducing the amount of stop-and-go traffic, and by using HOV lanes to encourage the adoption of zero- and low-emission vehicles.

HOV lanes encourage carpooling and discourage solo driving but that does not mean the net impact and the long-term impact is less congestion—the responses of other drivers need to be considered as well. If an HOV lane encourages solo drivers to carpool, other drivers may use the newly cleared



Automobiles enter a high occupancy vehicle (HOV) lane defined by paint striping on Ontario Highway 404 in 2010. HOV violation rates vary widely: In Tennessee, 45 to 85 percent of vehicles in HOV lanes have been in violation, while in Washington State, rates have been between 1 and 7 percent.

road space. This well-documented phenomenon, where drivers respond to the additional supply of road space by driving more, is called induced demand. Additionally, HOV lanes may draw users not only from the general-purpose lanes but also from transit, from not driving, and from alternative routes as well. This occurs especially if the HOV lane provides large time savings. Thus the number of carpools needs to be decided within the model (or endogenously), preferably as a function of the time and monetary costs of carpooling versus other modes of transportation.

The best studies account for the impacts of HOV lanes by using a traffic model to simulate the road network with and without HOV lanes. The best models allow for endogenous carpool formation and induced demand, and of those studies, half find HOV lanes increase traffic volume and the others

find that HOV lanes decrease traffic volume. Furthermore, the long-term impacts of HOV lanes are unknown, and there is reason to believe HOV lanes encourage sprawl by favoring longer commutes over urban roads.

HOV Lanes and the Environment

The 1990 U.S. Clean Air Act Amendments actively encouraged the building of HOV lanes by treating HOV lanes as an environmental tool. Through the Clean Air Act, the Environmental Protection Agency designates areas as nonattainment if they exceed federal air pollution standards. Nonattainment areas cannot build new highway or rail lines if they create or contribute to violations of the National Ambient Air Quality Standards. Nonattainment areas can build new HOV lanes because HOV lanes are considered a traffic control management measure. Thus, even though the impact of HOV lanes on traffic and air quality is unknown, HOV lanes are legally considered an environmental protection measure. There may be good reason for this. Even if HOV lanes do not decrease VMT, they may improve traffic flow and reduce idling, which can improve air quality. The long-term impacts of this are unknown and if induced demand effects are present, congestion may return. There is anecdotal evidence that HOV lanes are a compromise between environmentalists who want to reduce VMT and progrowth groups such as the American Automobile Association who would like to expand highways.

Public Support for HOV Lanes

The lack of consensus on HOV lane effectiveness in the academic arena is reflected in public attitudes toward HOV lanes. While the public seems to support many HOV lanes, some HOV lanes have been removed due to public outcry. The state of New Jersey removed HOV lane designations on I-287 and I-80 due to public protest. Florida converted Orlando's HOV lanes to general-purpose lanes due to high violation rates. If an HOV lane appears to be unused while the general-purpose lanes are congested, the public may pressure authorities to convert the HOV lane to a general-purpose lane, a condition some call "empty lane syndrome."

One solution to empty lane syndrome is to convert HOV lanes to high occupancy/toll (HOT) lanes. HOT lanes allow HOVs to drive for free or a

reduced rate but also allow low occupancy vehicles to drive on them if they pay a toll. Another solution to empty lane syndrome is to allow hybrid, electric, or other low-emission vehicles to use the HOV lane without meeting occupancy requirements. Allowing hybrids or other green vehicles to use HOV lanes often comes with unintended consequences, such as reducing the incentive to carpool by slowing down HOVs or subsidizing driving for those who bought a hybrid vehicle without the incentive.

HOVs and Transit

Research indicates HOV lanes have synergies with other ride sharing programs such as guaranteed ride home service, employer-provided preferential parking, and ride share cost subsidies. While undocumented, HOV lanes likely have synergies with transit that can be viewed as another form of guaranteed ride home and adds to the flexibility of HOV lanes. Bus rapid transit (BRT), which provides faster bus service than traditional bus routes, is an excellent option for carpoolers. BRT routes can save time on their dedicated BRT lane and these bus systems can expand their range by using HOV lanes. However, HOV lanes also likely draw passengers away from transit since those likely to spend extra time assembling a carpool are also those likely to spend extra time taking transit.

HOV lanes often motivate the practice of "slugging," or casual carpooling. Slugging is a form of hitchhiking that benefits the driver—who can now use the HOV lane—and the passenger—who receives a free or reduced-price trip to work. Slugging from northern Virginia into Washington, D.C., for instance, allows drivers and passengers to save time and money using the HOV lane, while slugging from Berkeley, California, into San Francisco allows drivers to pay a reduced toll on the San Francisco Bay Bridge. Slugging is likely enhanced by the ability in both cities to take transit for the return trip.

Compliance and Other Controversies

Driving in HOV lanes without meeting the HOV requirements is typically punishable by a fine, although enforcement rates vary. The Tennessee Department of Transportation has found that between 45 and 85 percent of vehicles in the HOV lanes are violating the HOV restrictions. Violation rates are much lower in other areas, especially

Washington State, where they are between 1 and 7 percent, partially in response to the HERO program, which allows other motorists to report violations via cell phone.

Drivers have been caught with mannequins in their vehicles in an attempt to drive in the HOV lanes as a single occupancy vehicle undetected. HOV requirements have also been used as a soapbox to argue about who and what is considered a person. In 2005 a pregnant woman in Arizona was stopped for driving in the HOV lane. She fought the ticket with the argument that her unborn child constituted a second person, thus entering the abortion debate as to when a fetus is considered a child. The judge denied her request, concluding that the additional person needs to fill a "separate and distinct" space in the vehicle. Similarly in 2013, a man from Marin County, California, drove in HOV lanes with only himself and the articles of incorporation for a business he owned. When pulled over, he argued the concept of corporate personhood allowed him to drive in the HOV lane, thus challenging the Supreme Court precedent that likens corporations to people. This challenge was also rejected.

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See Also: Bus Rapid Transit; Carpool Programs, Ride Sharing and; Carpooling; Carpooling, Casual; High Occupancy Toll Lanes; Road Pricing Schemes, U.S. and International; Single-Occupant Vehicle Trips; Travel Pricing.

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High Speed Highways

Many countries and regions today have highly developed systems of high speed highways used to transport goods and people safely and quickly across long distances. Notable examples include the U.S. Interstate Highway System and the International European Road Network. Investment in these highway systems has many purposes, including building a sense of national and regional unity, as well as facilitating the economic benefits believed to result from lower transportation times and higher speeds over long distances. However, some critics charge that the economic benefits are not always forthcoming and that, in the United States in particular, an emphasis on high speed highways has harmed urban areas and favored the automobile at the expense of other means of transportation.

United States

The idea for the U.S. Interstate Highway System dates back to a 1939 report (*Toll Roads and Free Roads*) to the U.S. Congress suggesting construction of a toll-free express highway network, and construction of such a national system of highways was authorized by the Federal Aid Highway Act of 1944. However, construction on the system did not begin until authorization of the Federal Aid Highway Act of 1956, signed into law by President Dwight Eisenhower (hence, the interstate system is sometimes called the "Eisenhower Interstate Highway System"). Roads in the interstate system are owned and operated by the states in which they exist, but in order to encourage construction, the federal government paid 90 percent of the costs and the states contributed 10 percent. The first section of the interstate to begin construction under

the 1956 law was in St. Charles, Missouri, and in 1992, the system as originally planned was completed. However, roads continue to be added and improved. The Interstate Highway System currently comprises almost 47,000 miles of roads.

The interstate system was designed to facilitate safe, high speed vehicle travel. Interstates are limited-access highways, meaning that one can only enter or leave an interstate through a controlled exchange rather than by an intersection, as is typical of slower-speed roads. Federal regulations also specify the width of lanes (12 feet) and shoulders (10 feet), and maximum grade (3 percent), and stipulate that interstates must be designed for safe travel at 70 miles per hour. Minimum bridge clearance was originally set at 14 feet, but this was raised to 16 feet for new construction or reconstruction in order to facilitate the transportation of large military equipment. Pedestrians, bicycles, and other nonmotorized vehicles are not permitted on most stretches of the interstate, although in some states bicycles are allowed to travel on the shoulder.

In a 1954 speech, President Eisenhower outlined the purposes of the proposed interstate system; these included improving road safety, reducing road congestion, boosting the economy, and aiding military and civil authorities in meeting the demands of a catastrophe or military emergency, including an atomic war. The safety standard was certainly met; innovations in roads and automobiles as well as changes in laws (for example, much stricter enforcement of drunk driving laws today than in 1954) have made automobile travel much safer in general, and despite the high speed of travel on interstates, their fatality rate was lower in 2004 (0.8 per million vehicle miles traveled) than the average for all U.S. roads (1.46 per million vehicle miles traveled).

It is more difficult to evaluate the influence of the interstate system on congestion, because patterns of land use in the United States have undergone dramatic changes since 1954. Some of this change was fueled by the creation of the interstate system, which facilitated the development of suburbs by making it possible to travel longer distances more quickly by automobile. Similarly, the economic effects are more difficult to assess, as discussed below. The military benefits are also less clear: certainly the military benefits along with everyone else by a national system of high speed highways, but the proposed benefits of providing quick evacuation

from major population centers have proven elusive. Instead, long traffic jams leading out of cities in the face of impending weather catastrophes have suggested that the interstates are not adequate for this purpose. Not considered among Eisenhower's points was the effect of the interstate system on urban life. This has been negative in many areas, according to some urban planners, as interstate construction has destroyed traditional neighborhoods, created blighted areas, and shifted the funding and planning emphasis away from public transit systems and pedestrian-friendly areas.

Europe

Transportation policy in most of Europe differs from that in the United States in that more resources are invested in public transportation, and a number of policy measures (such as high taxes on gasoline) make driving relatively more expensive. However, many European countries have well-developed highway systems, and the E-road system—a route designation system developed by the United Nations Economic Commission for Europe—makes long-distance international road travel easier. The E-road system (also known as the International European Road Network) was developed in the 1970s and is partly modeled on the U.S. interstate system; it uses consistent signage to identify roads by type (for example, reference roads, link roads) and direction (north-south or east-west). Roads designated as part of the Euroroute system, an international network (for example, the E5 runs from London to Istanbul), are required to meet certain design standards to facilitate safe high speed travel, including specified speeds, maximum gradients and minimum radii for curves, and visibility standards to allow for safe minimum stopping distances.

The best-known high speed highway network may be the *Autobahn* (“highway”) system in Germany, which has no general speed limit, although certain areas such as curves and construction zones do have posted limits, and there is a recommended speed limit of 130 kilometers per hour (81 miles per hour) for automobiles and motorcycles. The roots of the *Autobahn* lie in the AVUS (*Automobil-Verkehrs- und Übungsstrasse*, the “trial automobile traffic road”) in Berlin, a two-lane divided highway completed in 1921. During the Nazi period, the national high speed road was expanded as part of a national propaganda effort, and expansion of the

system accelerated from the 1960s onward, comprising a network of almost 8,000 miles by 2007.

Economic Effects

National and international high speed highway networks may include privately built roads (for example, some toll highways in the United States), but most of the funding for these systems, including the planning and policy making regarding road construction, routing, and so forth, generally comes from government sources. There is a general assumption that investments in highway infrastructure pay off economically, primarily by facilitating economic growth, but this proves to be a difficult question to examine on a macro level because of the broad reach of a highway network and the different economic circumstances of the regions through which it passes. Given the budgetary constraints experienced by many governments currently, the inevitable competition for government investment, and the sometimes politicized nature of the debate, it is worth considering whether the ruling assumption that investments in highway infrastructure yield productivity benefits and whether there are ways to identify how and where money invested in highway infrastructure will yield the greatest benefits.

Howard Shatz and colleagues conducted a meta-analysis of research on the U.S. highway infrastructure at the national, state, and substate level and of highway infrastructure in other countries. They found that studies at the national level tended to find strong productivity effects and rates of return for highway construction, mainly by lowering transportation costs for industry. Some studies at the state level also found positive economic effects, although generally at a lower level, while other studies found no effects or negative effects, particularly when considering the economy of neighboring states. At the substate level, results were even more mixed, with studies finding positive, negative, or no effects for the area where the investment was made, as well as in the surrounding counties or metropolitan area.

They also found several factors that were related to the success or failure of investment in highway infrastructure in specific locations, in particular that benefits are reduced if a nearly complete transportation network is already available, and that benefits are related to the condition of the infrastructure and the current level of congestion. In addition, they recommend that the economics of relatively large regions

be studied, because a benefit may accrue to the area directly related to the new highway while surrounding areas suffer, a result that does not necessarily lead to greater overall benefit, and that cost–benefit analysis be used to determine not only if there was a benefit but whether the benefit was worth the cost.

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See Also: Highway Design and Engineering; Highway/Road Capacity; Interstate Highway System; Traffic Flow; Traffic Safety and Risk Assessment.

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High Speed Rail, Design and Technology of

The increase in air travel during the 1960s and 1970s coincided with a large downturn in passenger travel on railways worldwide. As the luxury and novelty of air travel increased, railways were under growing

pressure to stop the hemorrhaging of passenger losses. Their answer took the form of high speed rail. But have the design and technological advancements in high speed rail been sufficient to win back the passengers and attract new ones to use the service?

High speed rail differs from conventional rail service in that it is a rail transport system that operates at a much higher speed than conventional rail travel and uses a dedicated track with its own specialized rolling stock. These trains run on standard-gauge tracks of continuously welded rail on a grade-separated right-of-way incorporating large turning radii in the design to combat the high speeds reached when traveling around curves. While high speed rail is usually designed for passenger travel, some high speed rail systems allow freight to be moved over their lines as well.

Origins

High speed rail development began in 1899 in Germany when a 17-mile (27-kilometer) stretch of railway line between Marienfelde and Zossen was electrified. Speeds of 130.6 miles per hour (mph; 210.2 kilometers per hour [km/h]) were reached using prototypes in October 1903, demonstrating that high speed rail travel would be feasible. However, it was more than 30 years later when regularly scheduled high speed rail travel was introduced between Hamburg and Berlin. Development continued until it was halted by the outbreak of World War II in 1939. The United States entered into high speed travel with the Zephyr service in 1934, running a regular route between Kansas City, Missouri, and Lincoln, Nebraska, with top speeds of 115 mph (185 km/h) and this was quickly followed by other services, although top speeds were much lower than the Zephyr.

Most European countries looked at high speed travel during the 1930s and Great Britain, in the form of a streamlined steam locomotive called “Mallard” achieved the official world speed record for a steam locomotive at 125.88 mph (202.58 km/h). However, time-consuming maintenance issues meant that the days of steam for use in high speed were numbered.

Spain had a major breakthrough in 1945 with the development of a streamlined articulated train able to run on existing tracks at higher speeds than contemporary passenger trains. The Tren Articulado Ligero Goicoechea Oriel (Talgo) system used a unique axle system with one axle set per car end

connected by a Y-bar coupler. Among a number of advantages, the center of mass was only half the usual height. Today Talgo is the main Spanish provider of high speed trains.

In the late 1950s development proceeded with the passing of 187 mph (300 km/h) but not without some serious engineering problems to solve. It was noted that when trains traveled at high speeds, extremely dangerous hunting oscillation (the swaying of bogies) would occur, leading to dynamic instability and potential derailment. Yaw dampers were invented and used to solve this problem, enabling the speed of 187 mph to be reached safely. “Current harnessing” remained a problem until a solution was discovered 20 years later by the French TGV high speed rail service.

At the same time, in Japan, congestion on both road and rail had become a serious problem. Not wishing to import petroleum for security reasons, Japanese railway engineers looked at the development of a high speed regular mass transit rail service to efficiently move its 45 million people around the country. The Shinkansen (meaning “new trunk line”) was born after 10 years of development and trials and reached speeds of 130 mph (210 km/h) with an average speed of 101.2 mph (162.8 km/h) between Tokyo and Osaka. Speed was one part of the equation; the Shinkansen was also a form of transport that could be used by the masses. The “bullet trains” initially had 12 cars, later increasing to 16 before double-deck trains increased capacity further. Over 10 billion people have used the Shinkansen—without a single fatality.

1960s and 1970s

The 1960s saw countries in Europe developing their own high speed rail, which led to a revival in rail travel in some countries. France was at the forefront of this with the creation of the Aérotrain, a hovercraft monorail train that reached speeds of 125 mph (200 km/h) and went on to reach speeds of 270 mph by 1974 in prototype phase. This was followed by the French National Railways, which in 1967 fitted the Paris–Toulouse line with new signal systems, curve revision, and an onboard “in-cab” signaling system so that trains could reach speeds of 125 mph.

The United States was not to be left behind, and the High Speed Ground Transportation Act of 1965 was passed to create a regular high speed service between New York and Washington, which reached

speeds of 120 mph (192 km/h), faster than the Acela Express trains operating between New York and Washington in 2012.

In the 1970s British Rail, the railway network of Great Britain, introduced a new high speed service that reached speeds of 125 mph (200 km/h), hauled by diesel-electric train sets. It was the fastest diesel-powered train in regular service in the world and was built with a reversible multicar set having driving power-cars at each end. Journey times were reduced considerably and passenger numbers soared.

France continued to develop its technology and design of high speed rail and saw the use of gas turbines as a means of achieving the power required to operate the trains. This was used on a prototype involving an undividable set of five cars and two power-cars at each end, each power-car powered by two gas turbine engines. This prototype also used Jakobs bogies, which were shared by two cars to reduce drag and increase safety.

These developments continued until the French railways (SNCF) placed an order for 87 TGV Sud-Est train sets. This definitive train combined the various designs and technologies of the previous decade, resulting in an undividable set of eight cars, sharing Jakobs bogies, and hauled by two electric power-cars, one at each end. In 1981, the first section of the new Paris–Lyon high speed line was inaugurated with a top speed of 168 mph (270 km/h).

Recent Developments

Over subsequent years and with the advancement in technology and design, speeds of 237 mph (380 km/h) in 1981, 320 mph (515 km/h) in 1990, and 358 mph (574 km/h) in 2007 have been reached. With these top speeds, a new dedicated high speed line and complete capability with the existing network, the TGV can link every major city in a shorter time than before. This has led to air traffic on some of these routes decreasing or disappearing altogether.

Germany and France have continued to embrace high speed rail, with Germany developing a train similar to the French TGV, with streamlined motor cars at each end and a variable number of trailers between them. However, these trailers have the classical two bogies per car, allowing cars to be decoupled. Spain now has the largest high speed rail network in Europe and second only to China in the

world, after announcing in 2005 an ambitious plan to have 90 percent of the Spanish population living within 50 kilometers of a high speed rail station.

The United States abandoned high speed rail after its initial foray in the 1960s, and it wasn't until 1993 that the United States began to take note of the popularity of high speed rail travel in Europe and China. The Acela Express made its debut in 2000 on the Boston to Washington line, linking these cities with New York, Philadelphia, and Baltimore. This service operated at a profit, but unlike other high speed rail services, it lacks a dedicated line.

High speed rail was high on the political agenda in 2008 but no projects have yet commenced and are unlikely to do so before 2016. The California Proposition 1A (2008) approved the California High-Speed Rail network, but work on this project has yet to start nearly five years later. In 2012 the president of Amtrak proposed a \$151 billion dedicated high speed rail line between Washington, D.C., and Boston but it would take 25 years to fully design and build the line.

The greatest expansion in design and technology of high speed rail has occurred in a number of east Asian countries. Japan, South Korea, and China have embraced high speed rail and have taken it to another level.

South Korea launched its first high speed rail line in 2004 between Seoul and Busan, the two largest cities. Construction began in 1992 and the first commercial service launched some 12 years later. The top speed for trains in regular service is currently 190 mph (305 km/h), though the infrastructure has been designed for speeds up to 220 mph. Subsequent developments have seen speeds of 262 mph (421 km/h) achieved on other lines.

China has come rather late to the scene regarding high speed rail, with initial interest beginning in the early 1990s, but it has embraced the concept of high speed rail and has been busy expanding the service across China. The original aim of the Chinese Ministry of Railways was to research and develop domestic technology of high speed rail to a world standard. China successfully created a train set that operated at 300 km/h but it suffered poorly in regular service. To overcome this problem, it purchased high speed trains from French, German, and Japanese manufacturers, together with technology transfer contracts to improve its own ability.

As of 2011, China had the world's longest high speed rail network with over 8,300 kilometers of track that is still being increased with the intention of creating the 4+4 National High Speed Rail Grid by 2015. China also has the longest high speed rail line between Beijing and Shenzhen, covering a distance of 1,372 miles (2,208 km).

Design

Track for high speed rail networks is usually of a continuous welded type of rail, which is the most effective for reducing track vibration and misalignment. The continuous welded track usually rest on traditional sleeper and ballast, such as the French high speed lines, or on concrete tiles as is the case with German and Chinese high speed lines. The most common track gauge for high speed rail is 1435 mm standard gauge.

Almost without exception, high speed lines are electrically driven via overhead cables and have in-cab signaling, all developed over the previous decades. Advanced switches are also used, using very low entry and frog angles. High speed rail lines are efficient forms of transport movement as constrictions, such as at grade-level crossings, are eliminated. Japan and China typically construct their high speed lines elevated from road level, which allows for safe high speed travel at a much lower cost.

Another design feature of high speed rail is the avoidance of sharp curves, allowing for much higher speed limits. Curve radii are usually above 2.8 miles (4.5 km) with radii of 4.3 to 5.6 miles (7 to 9 km) for lines capable of reaching speeds up to 220 mph (350 km/h). On high speed curves the outer rail is usually 150 mm higher than the inner rail to create a 1:10 banking angle.

To reduce any effects from the surrounding environment, trees are usually cut and removed in a large area away from the high speed line and fences erected to prevent animals and humans from walking on or across the tracks.

Technology

Modern high speed trains differ from the earlier form of high speed trains that had one or two locomotives with traction motors. These were often positioned at the front of the train as a pair or at the front and rear to better distribute the tractive forces.

The modern high speed trains now have traction motors in every car, giving better force distribution and more comfort for the passenger. The train can also accelerate and decelerate faster as the power is distributed over more axles as the powered wheels rely on friction between the wheels and rail to transmit power. High speed trains also carry dry sand, which is dropped in front of the powered wheels to increase frictional forces in the event of ice or wet leaves on the rail line.

On a typical 16-car train set there are 32 traction motors, so half of the axles are powered as each car travels on a pair of two-axle bogies. With each motor contributing 600 kilowatts (kW), or 800 horsepower, the entire train set generates 19 megawatts of installed power with energy consumption averaging around 0.08 kW-hour/mile/seat.

When high speed trains start to roll, they accelerate at 1.6 feet per second squared (f/s^2), which eventually increases to around 3 f/s^2 , the upper limit that passengers can feel comfortable with. Braking deceleration is also around 3 f/s^2 , which would result in a train traveling 200 mph taking about 2.4 miles to come to a halt.

Most high speed trains get electricity from overhead wires or catenaries using a pantograph. The biggest challenge with using pantographs to take power from the catenary is keeping the contact forces between the two within a certain range—not too much friction but enough contact to make a solid electrical connection. In icy conditions two pantographs are used, with the front pantograph knocking the ice off for the second one to make the connection.

High speed trains also feature regenerative braking, which uses the traction motors as brakes and generates electricity. This electricity can then be fed back through the overhead lines to power another train as this electricity cannot be stored on board the train and is rarely fed back into the grid. If the electricity cannot be reused, it is burned off in roof-mounted braking resistors—known as rheostatic braking—or the train switches over to friction braking.

The preferred method of braking for high speed trains is regenerative braking because it minimizes wear and tear and saves energy, but these trains also carry electro-pneumatic friction brakes outfitted with steel discs and sintered pads designed for big loads. High speed trains have two levels of

emergency brakes. The first level uses all forms of brakes onboard. The second level is used in the event of no electric power so only friction braking comes into play.

Aerodynamic technology is constantly developing, as up to 60 percent of the tractive force can be lost due to drag and friction. Aerodynamics also need to make the train stable due to the fact that as speed increases, the cross-wind stability decreases. The four main areas that are looked at aerodynamically are the lead car with its streamlined nose and body; spoilers on top and underneath the cars; stowing and deployment of the pantograph and fairings around the bogies (the underlying framework), between the cars, and covering the underside of the train. The fairings also prevent any damage to the wheels and axles from track ballast or small foreign objects that may be on the track.

Streamlined fairings on the roof-mounted equipment limit the sonic booms when entering tunnels, as well as cutting down on drag. A smoother streamlined roof cuts down noise as well. When high speed trains pass each other at around 190 mph (300 km/h) 91 decibels of noise is produced, but only 72 decibels is heard inside the car due to sound-dampening coatings on the inside skin of the car. There are also noise absorbers on each set of wheels as well as air-spring bellows between the bogie and car body to aid in the reduction of noise inside the carriage.

HVAC is another area that has undergone technological development. Extreme temperatures can affect electricity usage on high speed trains by up to 30 percent. To achieve minimum electrical wastage, air intake units are based on passenger occupancy, and before venting cabin air outside to keep air inside fresh, it is routed through heat exchangers to preheat or precool incoming air. This allows the HVAC equipment to reuse up to 80 percent of the energy spent cooling or heating the cabin air.

The cost of constructing a two-track high speed rail line has been estimated by the U.S. Government Accountability Office at \$50 million per mile, although this can vary depending on the type of train; whether the rails run through urban areas, underground, or empty countryside; and how many roads and other railways need to cross over or under the high speed rail line.

The overhead lines also need to be factored into the building costs, as well as the type of track the

high speed rail will use: ballast track or slab track. The more traditional type of track, ballast track has cross-ties between the rails that are kept in place by gravel (ballast), whereas the slab tracks mount the rails on concrete track rather than using ballast. Slab track costs more to build but is less expensive to maintain.

Annual maintenance costs on high speed rails vary, with a European study showing costs at \$140,000 per year per mile while a British study has the annual cost at \$493,000 per mile. The reason for the high costs is that as speeds increase, tracks need to be inspected more often and built to tighter alignment tolerances.

Has the design and technological advancement in high speed rail been enough to win back passengers lost to the airlines and attract new customers? With a reported increase in passenger usage on high speed rail lines, it would appear so. The advancement in design and technology in high speed rail over the last four decades has proven to be a good investment, along with the modern terminals and the ability to travel from the heart of one city to another without the need to drive to an airport, spend two or more hours in a terminal building, and then land at another airport requiring a taxi or other form of transport to get to the city. High speed rail has an exciting future ahead.

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See Also: Federal Railroad Administration; High Speed Rail, Policy and Planning of; High Speed Rail, Safety Issues of; International Rail Transit; Transit Lines/Networks.

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High Speed Rail, Policy and Planning of

High speed rail has experienced rapid development in many countries of the world in recent decades. The development of high speed rail is a systematic process that involves route and station planning, technology innovation or adaption, financing, and many other considerations. As part of the public infrastructure systems, the development of high speed rail projects must also be bound by regulations and policies. Planning and policy of high speed rail are inextricably linked.

Because of differences in national conditions, the planning and policies of high speed rail in various countries differ. This introduction covers the core issues related to high speed rail planning and policy. Planning and policies of high speed rail are discussed in the context of different countries, including both the high speed rail that is already developed in such nations as Japan, France, and Germany, as well as the high speed rail that is still developing in China, Spain, and the United States.

Overview

Planning and policy of high speed rail can be defined as all the arrangements of planning, legal policies, and regulations for high speed rail development. In general, the core of high speed rail planning and policy relate to three elements. The first element is location plans for the high speed rail route and stations. Location planning considers the geography and topography of routes and distribution of stations. The fundamental purpose is to avoid complicated geological terrains in order to reduce construction costs and ensure operational safety. In addition, the location planning of the high speed rail route and stations also considers economic efficiency and regional development.

High speed rail can only obtain economic efficiency when it is designed to serve regions with high population density where intercity travel demand is potentially high to justify its construction and operational costs. High speed rail also facilitates regional economic development when it is designed to link regions with labor markets and job opportunities. In order to achieve these objectives, criteria and standards of high speed rail route and station planning are usually addressed

explicitly in the form of high speed rail development policies.

The second element of high speed rail planning and policy relates to the question of how to develop and effectively utilize high speed rail technology. The review of different countries' high speed rail developments indicates that there are at least two strategies for the development of high speed rail technology. The first strategy is to establish and develop one's own technology through independent innovation. This approach is very costly to implement, requiring a large investment in research and development. Countries including Japan, France, and Germany followed this approach and developed their own high speed rail technologies. The second strategy, which is less costly, is to adapt and utilize other countries' technologies through purchase and transfer. Some countries may further re-innovate and localize high speed rail technologies through establishing joint-venture companies with foreign manufacturers.

The high speed rail systems in Spain, China, South Korea, and the United States are developed through this approach. Given the complexity of high speed rail systems, selecting a suitable development strategy is critically important. It affects the economic vitalities of many domestic railway-related industries and also has significant influences on the national economic development. Therefore, the development of high speed rail technology is a vital component of high speed rail planning and policy.

The third element of high speed rail planning and policy is financing. The development of high speed rail is not affordable for any individual or company. Instead, it requires a strong commitment of national financial support. Due to the different national public financial conditions, high speed rail financing mechanisms can vary substantially. Generally, public financial support is needed to ensure the success of a high speed rail project. Other mechanisms such as issuing bonds, bank loans, attracting foreign investment, and public-private partnership investment are also used as primary or complementary funding.

It is clear that the context of high speed rail planning and policy varies across countries in different time periods and for different projects. In order to better understand the similarities and differences of high speed rail planning and policies, the following discusses the experience of six countries:



A Central Japan Railway Company Shinkansen train glides on the Tokaido line in 2008. The Tokaido Shinkansen opened in 1964, making Japan's high speed rail system the first to be developed in the world. Its trains now carry more passengers than any other rail system worldwide, with a total ridership estimated at 5.3 billion on the Tokaido line since it opened.

Japan, France, Germany, China, Spain, and the United States. This includes those countries that have already developed and are utilizing high speed rail, such as Japan, France and Germany, and those countries still in the development phase of high speed rail development and implementation, such as China, Spain, and the United States.

Japan

Japan was the first country in the world to develop modern high speed rail technology and infrastructure. Although the Japanese high speed rail system was built through public investment, it has now been privatized. The high speed rail planning and policy in its early development was implemented by the Japanese National Railways (JNR), which was a state-owned company. Following World War II, Japan was eager to revive its economy. The development of a new high speed passenger railway connecting Tokyo and Osaka became the primary

concern of Japanese transportation leaders and politicians. The plan was regarded as a practical and implementable strategy intended to revitalize the most dynamic economic corridor in Japan.

Because of strong research and development (R&D) capabilities in railway technology as well as the effective lobbying efforts by Japanese politicians, the Tokyo–Osaka high speed rail project obtained up to 194.8 billion yen in public financial support in 1958, which was equivalent to approximately \$4.07 billion in 2010. Though the construction costs were later found to be double the original estimate, JNR was able to complete the Tokyo–Osaka Shinkansen passenger system with financial aid from Japanese government investment and World Bank loans.

France

France was the first country in Europe to develop high speed passenger rail. Similar to the Japanese experience, the French high speed rail planning

and development policies were not led by the state Department of Transportation but by the French National Railway Corporation (SNCF). During the late 1960s and early 1970s, SNCF began to research and develop its own high speed rail technology called *Train à Grande Vitesse* (TGV), meaning “high speed train.” In order to reduce the impacts of public financial cuts due to the French economic stagflation in 1973, SNCF made several planning adjustments to the first French high speed rail route connecting Paris and Lyon.

According to the revised plan, two-thirds of the rail line would be newly built and the remaining one-third would utilize the existing railway lines that were mostly located in urbanized city areas. The strategic adjustment later proved to be a success as construction costs were dramatically reduced and the passenger travel time between Paris and Lyon was also reduced from the original four and a half hours to only two hours and 40 minutes.

Germany

Germany is another nation that developed its own high speed rail technology. Despite being part of the European Union (EU), the German system significantly differs in high speed rail planning and policy from the system in France. These differences are mainly reflected in route planning and technological specifications. Because Germany is a federal state, high speed rail planning and development policies needed to take different political interest groups into account. Deutsche Bundesbahn (DB), or the German Federal Railways, has a more dispersed interest structure than that of its French SNCF counterpart.

For example, the initial German high speed rail route plans reflected the special considerations for regional balance of service distribution and rail investment. Instead of proposing an integrated new high speed rail route for the German Inter-City Express (ICE) trains, two segments of new infrastructure were planned and selected in both south and north: the Hannover to Würzburg ICE line would serve northern Germany and the Mannheim to Stuttgart ICE line would serve the southern region of Germany.

In general, planning and policies of high speed rail in Germany required the development of new infrastructure to connect more regions so as to serve a broader public, which normally has to constrain the advantage of fast speed.

In addition, unlike the centralized political system in France, high speed rail development in Germany was a compromise between various political groups and interest groups. As a result, the planning and policy of high speed rail had to coordinate and accommodate different views. For example, in order to satisfy the environmental groups and organizations, high speed rail planning and policy in Germany had to give greater consideration to environmental issues than Japan or France.

Inevitably, this increased construction costs because of the designs and applications of tunnels, viaducts, noise barriers, and other techniques to reduce the environmental impact. Further unlike Japan or France, the German system had to accommodate freight movement to a greater degree than the other two. This was important for support from manufacturers and export industries as well as for the federal states where these industries are concentrated.

China

China has the highest high speed rail mileage in the world after a decade of investment and construction. Unlike Japan, France, and Germany, high speed rail planning and policy is a governmental activity, which is the responsibility of the Ministry of Railways (MOR) of the People's Republic of China. The earliest planning and policy making for Chinese high speed rail was initiated in the 1990s. The MOR submitted the “Beijing–Shanghai High Speed Railway Program Concept Report” to the National People's Congress, which was the first proposed high speed rail development plan. With the rapid growth of the Chinese economy, the existing passenger rail service was not able to meet the exponentially increased travel demand. High speed rail development became necessary to expand passenger rail transport capacity.

In 2004, the State Council approved China's first Mid-Long Term Railway Network Development Plan, which proposed the idea of building four vertical (north–south bound) dedicated high speed rail passenger lines and four horizontal (east–west bound) rail lines to connect the country's major economic centers. The State Council later adjusted the plans twice, in 2007 and 2008, which ultimately expanded total high speed rail track length from 7,456 miles (12,000 kilometers) to 9,942 miles (16,000 kilometers).

Although China attempted to develop its own high speed rail technology at the early development stage, MOR later decided to develop the high speed rail system through acquisition of foreign technology. Chinese railway manufacturers collaborated with high speed rail manufacturers from Japan, France, and Germany to achieve high speed rail technology absorption, transfer, and localization. China also implemented a short-distance (18.95 miles) high speed rail from Shanghai to Shanghai Pudong International Airport using German maglev technology.

This was the first large-scale utilization of this technology for commercial operation worldwide. In terms of the financial concern of high speed rail planning, the major financial support was from the central government. Other financial sources, including local government investment, bank loans, foreign investment, and issuance of railway bonds were also widely utilized.

Spain

As of the end of 2012, the total length of high speed rail tracks in Spain reached 1,656 miles (2,665 kilometers). This makes Spain's high speed rail network the second largest in the world. Similar to China, there was significant high speed rail investment by the Spanish government. Spanish high speed rail development has been rapid and recent. The high speed rail network connects the capital city Madrid to several major cities such as Barcelona, Seville, Valladolid, Toledo, Albacete, and Valencia. The network also reaches to the French city Perpignan with connections to TGV, symbolizing the linkages with the European high speed rail network.

High speed rail planning and policy is managed by the Spanish Ministry of Transport. The high speed rail technologies are based on the French TGV and the German ICE experiences. The major financial source for Spanish high speed rail came from state revenue involving a number of administrative departments. In addition, Spain also received large European subsidies for high speed rail construction.

For example, the total cost of the Madrid–Valencia high speed line is 12.4 billion euros, of which 1.949 billion euros was from EU subsidies. Other high speed rail projects, such as the one connecting Madrid to the French border, received EU funding

of 3.389 billion euros. In addition to the central government and EU support, some regional governments also contributed to the high speed rail projects that serve their jurisdictions.

United States

Passenger rail service in the United States accounts for only a small proportion of the intercity travel market. Currently, there is only one so-called high speed train service—Acela Express—which is operated by the National Passenger Railroad Corporation (Amtrak) between Washington, D.C., New York, and Boston in the Northeast Corridor. By the definition of the Union of International Railways (UIC), it is a high speed rail as its top speed can reach 150 miles per hour (mph); however, due to the limitations of its obsolete track and signal systems, the service runs at lower speed during most of the sections. The planning and policy of U.S. high speed rail are not subject to sustained attention as in other countries. The main reason is the American democratic political environment as well as the dominance of highway and aviation within the transport system.

High speed rail development policies were seriously considered by the government only twice in U.S. history. The first time was in 1965 when President Lyndon B. Johnson advocated the development of a high speed rail line. Because of his effort, the United States experienced a period of high speed rail R&D in the late 1960s. As a result, two types of high speed train technologies, the Turbotrain and the Metroliner, were developed and served the northeast travel market for a period of time.

The second time was in 2009 when President Barack Obama took office. The American Recovery and Reinvestment Act of 2009 for the first time in the U.S. history allocated \$8 billion of public money to support research, planning, and construction of high speed rail. The support was extended as Congress allocated another \$2.1 billion in 2010. In accordance with the requirements of the Passenger Rail Investment and Improvement Act of 2008, President Obama officially announced the new plan for development of a U.S. high speed intercity rail program on April 16, 2009. The plan outlines priorities for 11 high speed rail lines.

The new plan suggests that a U.S. high speed rail service could serve 80 percent of Americans in the next 25 years. Although the high speed rail plan

was proposed with a series of objectives, such as stimulating economic development, reducing oil dependence, and promoting traffic efficiency, the U.S. high speed rail policy is also generally considered a political solution for job creation in a recession period. Long-term commitment is still uncertain.

High speed rail development in the United States faces many challenges. Similar to Germany, railway planning and construction in the United States are influenced by special interest groups, ranging from competing transport such as airlines to not-in-my-backyard (NIMBY) and environmental groups. Negotiation with these groups can be very challenging and time consuming. In addition, the lack of a sustainable and long-term financing mechanism makes high speed rail development hardly a reality for the United States in the short term.

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See Also: High Speed Rail, Design and Technology of; High-Speed Rail Investment Act of 2001; National Railroad Passenger Corporation/Amtrak; Railroads, Passenger.

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High Speed Rail, Safety Issues of

Plans have been made in the United States to develop high speed rail (HSR), defined as intercity passenger rail service reaching speeds of at least 110 miles per hour. The U.S. Department of Transportation (DOT) High Speed Rail Strategic Plan 2009 proposes the creation and expansion of a network of high speed rail corridors in the country.

One of the strategic transportation goals in the plan is to ensure the safe movement of goods and people, a huge challenge given the ambitious nature of the plan. Moreover, in spite of the fact that regulations emphasize the importance of crash survivability, the issue of crash avoidance should take priority over crash survivability.

Railway accidents are a common occurrence, the causes of which range from drivers' errors (including excessive speed) to mechanical failures. Take, for example, the Chatsworth train collision in southern California in 2008, in which 25 people died. A safety backup system could have prevented the train from going through a red signal. Had positive train control (PTC) been used, the accident might not have happened. High speed trains have also been involved in collisions leading to significant fatalities. The Eschede train disaster in Germany in 1998 resulted in 101 people losing their lives.

Key Measures

In the United States there were several fatal rail accidents between 2002 and 2008. In response Congress adopted the Rail Safety Improvement Act of 2008 (RSIA), which constituted the first authorization of the Federal Railroad Administration's (FRA) safety programs since 1994. The RSIA requires the FRA to, among other things, develop new safety regulations. These regulations cover different areas related to railroad safety, such as hours of service requirements for railroad workers, positive train control implementation, standards for track inspections, certification of locomotive conductors, and safety at highway-rail grade crossings.

Crucially, the act requires the introduction of PTC systems on every main line that is used by intercity rail passengers or commuter rail passengers on a regular basis by the end of 2015. The PTC

systems are designed to react automatically to the emergency situations by slowing down or stopping a train. These systems are programmed to avoid the most dangerous situations, such as head-on collisions or derailments due to excessive speed.

The current safety standards depend on operating speeds. Thus, trains traveling between 80 and 90 miles per hour (mph) trigger the five lowest safety standards (classes 1–5) whereas the operators of the trains running at speeds over 150 mph must comply with the highest (class 9) safety standards and a special order that governs the operating systems. Trains running at the following speeds, 91 to 110 mph, 111 to 125 mph, and 126 to 150 mph must adhere to the class 6–8 safety standards, respectively. The current plans to develop high speed rail (HSR) systems running at around 110 mph may not require the highest safety standards.

Safety Standards Review and Development

The FRA's High Speed Passenger Rail Safety Strategy provides a good overview of the existing and planned safety standards. The FRA acknowledges that it is looking at the safety standards developed in Europe and beyond, where trains can travel up to 220 mph. It highlights that the American track system differs significantly from the systems in other countries. The former has been built primarily for freight transport whereas the European tracks serve primarily as passenger rail.

This difference poses a greater challenge for the U.S. stakeholders to develop HSR services. The FRA is also exploring other avenues for improving safety standards through its rulemaking. Crucially, in order to address the issue of prevention discussed above, the FRA is reviewing the preventive measures in place and the potential developments in this area.

Take, for example, a proposed staggered approach for PTC systems. Thus trains running at higher speeds will require more stringent PTC systems such as “fail safe” for trains operating at 90 mph or special preventive analysis for trains running at 125 mph. Moreover, in terms of prevention, the FRA is looking into vehicle track interaction, grade crossing safety, maintenance-of-way safety management, right-of-way safety, and real-time system monitoring.

The FRA is also looking at the mitigation of damage that might occur in emergency situations.

Currently, the Passenger Equipment Safety Standards distinguish between two tiers of equipment. First-tier equipment can be used in emergencies involving passenger trains traveling up to 125 mph and on the freight system. Second-tier equipment can also be used on freight systems passenger trains running up to 150 mph. The two-tier system has already been criticized by many stakeholders for not being failure proof and not adequate to be used beyond freight tracks.

Further, the agency is learning from outside U.S. operators who have tested and used highly innovative systems for predicting the survivability rates in different conditions and complementary risk reduction measures, such as signaling systems, that allow for the maximum levels of crash avoidance. The FRA is also looking at the distribution of passengers among cars and fuel tank integrity.

Speed-Neutral Requirements

Most of the safety standards address the prevention and mitigation of accidents, which are often perceived to be caused by speed. The safety standards also include the ability of emergency services to respond quickly to the emergency situations with maximum preparedness. Swift response can reduce damage and save lives.

There are a number of management systems developed by the FRA and the American Public Transportation Association's Passenger Rail Equipment Safety Standards Task Force in anticipation of HSRs. The agencies and other stakeholders are also working on system safety standards, which allow for the identification of safety needs and managing them over long time horizons.

Further, the speed-neutral measures are concerned with, among other things, the hours of service, specialists' training and certification, misuse of alcohol and drugs, and workplace safety. Some of these speed-neutral measures have also been identified as inadequate for HSRs.

The FRA established a Railroad Safety Advisory Committee (RSAC) in 1996 to work with all stakeholders in the rail community to develop new regulatory safety proposals. RSAC, including its specialist task forces, has been working on safety standards dedicated to HSRs. It has looked, for example, at the following issues: strategies for the disabled, emergency lighting, evacuation, luggage retention, and window glazing standards. Many of

these matters constitute speed neutral measures that must be reviewed, especially in anticipation of high speed rail.

Dark Territory Safety Enhancements

Dark territory is a term used to describe the railway track sections without installed or operational signaling and control system equipment. It is estimated that dark territories compose at least 40 percent of U.S. railway lines. Section 406 of the RSIA requires the secretary of transportation to “prescribe standards, guidance, regulations, or orders governing the development, use and implementation of rail safety technology in dark territory.”

The main task is to develop regulations to cover technologies such as remote-control switches, high water or earthquake detectors, and grade crossing video monitors. Currently, the RSAC’s Dark Territory Group is considering which type of regulation should be used for specific technology.

The main question is whether to use prescriptive regulation, often very costly at the implementation stage, or performance-based regulation that focuses on the desired outcome and may be costly at the initial stages of development and drafting. One possible scenario, presented unofficially by the FRA, is a mixed approach. Thus, a rule would cover each technology and would envisage voluntary participation in the use of the technologies.

The rule would be accompanied with guidance that would prescribe minimum requirements for each technology. The railroad operators would have to establish “dark territory technology plans,” to be approved by the FRA, in which they would explain how they intend to meet the minimum requirements specified in the guidance document. The FRA would subsequently audit the operators and hold them accountable for following their plans. It is not clear at this time whether this approach will be adopted formally.

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See Also: High Speed Rail, Design and Technology of; High Speed Rail, Policy and Planning of; Trains.

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High-Speed Rail Investment Act of 2001

The High-Speed Rail Investment Act of 2001 was introduced into the House of Representatives (H. R. 2329) on June 27, 2001, by Representative James Oberstar (D-MN), Chairman of the House Transportation and Infrastructure Committee and 124 other members. It was joined with S.B. 250. The bill’s proponents urged its passage as a way to urgently address highway congestion, which was costing the nation an estimated \$100 billion in lost productivity. The bill, when enacted, would begin the development of a system of high speed railways.

Railroads have been carrying passengers since the 1840s. From the 1850s to the 1950s they were the major form of overland transportation. The advent of interstate highways in the United States and super-highway systems designed to carry large volumes of passenger automobiles around the world has led to a decline in passenger train travel. However, new faster high speed train systems have been and continue to be developed for carrying passengers.

The high speed rail systems operate at much faster speeds than those used by older, traditional passenger trains. The newer systems used standard gauge rails that are continuously welded. The tracks are laid on a uniform railbed that has its own right-of-way and on curves has a turning radius that is not a threat to stability inside the train nor to derailment of the train from a failure to maintain the rails.

International High Speed Rail

In 1964 Japan opened its bullet train system that attained speeds of 100 miles per hour. However, improvements have allowed the speeds to gradually increase to much higher speeds. Called the Tokaido Shinkansen, it was operated by the Japanese National Railways (JNR). Since 1987 it has been operated by the Central Japan Railway Company (JR Central). Today it has the highest passenger volume of any train in the world. There are local trains in Japan, but these take much longer to go the same distances. The bullet train connects cities such as Tokyo and Osaka with rapid service, but the price of tickets for individuals is expensive. Many people purchase a rail pass that permits unlimited use. Others are supplied with tickets their company purchases as a business expense.

In more recent decades many countries have developed high speed rail lines that connect their major cities. The most prominent countries are China, France, Germany, Italy, Turkey, South Korea, Spain, and Taiwan. Today's high speed trains usually travel at maximum speeds of 185 miles per hour (mph). Most of the high speed rail systems are designed for passenger traffic; however, some high speed freight systems are being built, such as the French mail service, La Poste.

China is developing a national high speed rail system. It is accused of having stolen the technology for its systems from the company that builds the bullet trains in Japan. The system is connected to the Shanghai maglev system that runs from the airport to downtown Shanghai at speeds of more than 200 mph.

U.S. High Speed Rail

The United States was the world's leader in railroad development in the 1800s. Railroad companies, often with government land grants, created a huge network of rails across all of the country. However, by the 1960s most of the American railroad companies were abandoning passenger service for freight hauling. The great expansion of the Interstate Highways System and the higher levels of prosperity following World War II coupled with very cheap gasoline made automobile travel very easy and more affordable than other forms of travel.

A major factor in the end of rail service, including light rail and trolley service, was the purchase of streetcar companies and electric trains by the

General Motors Company in a conspiracy. In what is also called the Great American Streetcar Scandal, the General Motors Company sought to eliminate competition for its automobiles in U.S. cities. As a result, several generations of Americans grew up without any rail service experiences. However, by the end of the 20th century, the enormous increase in traffic and the distances commuted were creating traffic jams, driver fatigue, and environmental issues as ever larger highways had to be built. Consequently, many Americans began to reexamine travel by passenger train service.

In the United States, the federal government has defined high speed rail service as service that operates in excess of 110 mph. Only one rail line meets this definition—the Acela Express operated by Amtrak. It is slowed by the fact that it does not operate over a dedicated track but has to share it with conventional rail service on its Boston–New York City–Washington runs.

Plans for a high speed rail system in the United States have been circulating since the 1960s when the High Speed Ground Transportation Act of 1965 was adopted. The act was partly a response to the Japanese bullet train. One outcome was the New York–Washington Metroliner service. However, little has been accomplished since, although there are many plans for a system that would have trains moving at 220 mph on dedicated routes across the country.

The Act

In 2001 Congress passed the High Speed Rail Investment Act (HSRIA). The aim of the act was to help the National Railroad Passenger Corporation (Amtrak) raise funds for capital investment. Over the previous 30-year history of Amtrak, it had received over \$25 billion from the federal government, including an appropriation of \$521 million for fiscal year 2001. The cost of operating the line was not being met by revenues. Though its revenues had risen in recent years, its costs had risen even more, and it was not generating sufficient revenues to stay in business. So if Amtrak were to continue to provide rail service across the United States, and especially in the northeast urban corridor, it was necessary to provide federal financial assistance to pay for its operating and its capital maintenance and development costs.

The HSRIA authorized Amtrak to issue up to \$12 billion in “tax credit bonds” between 2001 and

2011. Tax credit bonds pay lenders in “tax credits” rather than interest. So when calculating the value of the bond, the bondholder calculates the impact of the tax credit upon its federal (and state if applicable) tax bill. The savings in taxes might well be more than the profit after taxes from interest on the bond so they are desirable to bondholders in high-income brackets.

The proceeds from bond sales would go into an interest-bearing trust account, however, those proceeds would have to be spent within three or four years to comply with the arbitrage provisions of the act. The Congressional Budget Office (CBO) analysis suggested that the account’s trustee would have difficulty finding investments that would provide a sufficient return to repay the principal.

The HSRIA bond money was to be used to pay for capital improvement projects that are dedicated to high speed rail. Most of these are in the Amtrak Northeast Corridor. Essentially, the HSRIA amended the Internal Revenue Code of 1986 to allow a tax credit to holders of qualified bonds issued by Amtrak. It also amended Title 49 of the U.S. Code to grant authority to the secretary of transportation to approve projects that would be funded by HSRIA tax-credit bonds.

Cost analysis of the HSRIA’s funding mechanism for a high speed rail system was unclear because the cost to build a high speed rail system in the United States is not known. The Northeast Corridor alone would cost at least \$100 billion. However, before the adoption of the HSRIA, the House of Representatives received a report it had requested from the CBO on the financial implication of the tax credit bonds. The CBO report considered only the financial implication of the funding and not transportation policy.

The CBO reported that the bond would have an impact of about \$7.4 billion in “present-value terms” (that is, the value of money in 2001). The states would also lose about \$1.8 billion in tax revenue on the bonds as a tax credit vehicle rather than a tradition interest-bearing vehicle. The total government cost would be about \$9.2 billion. However, the CBO expected the bond program would raise only about \$8 billion (in 2001 value) for Amtrak. This method of funding, the CBO concluded, would be 15 percent more expensive than simply funding Amtrak with \$8 billion in appropriations and matching state grants. Therefore, the tax credit funding method

would be a new approach that was more expensive than just outright federal assistance.

The bonds would mature in 20 years, but there were a number of other issues noted in the CBO report. The issues included the securing of buyers for the bonds, the security of the bond capital, and the possibility of changes in Amtrak’s future status creating unforeseen tax liabilities for bondholders. Another issue was the tax liability of income from the capital in the bond capital trust fund.

The CBO concluded that the bond program was also more expensive than the issuance of tax-exempt federal and state bonds with the principal repaid from government funds. It also concluded that the tax credit bonds would obscure the true cost of what was really a new spending program that would reduce tax collections, with the subsequent impact on federal and state budgets.

The CBO noted a major problem with the legal status of Amtrak. In theory it was a private company. A number of private railroad companies had common stock certificates of ownership that had been given to them in compensation for their track and rolling stock that had been taken when Amtrak was organized in 1970. However, the stock was essentially worthless, and even if there were any profits, the secretary of transportation, as the owner of all preferred stock shares, would be first in line to claim them. The plain fact, the report noted, was that Amtrak was financially dependent upon the federal government and would go bankrupt without its support.

The legal fiction of Amtrak’s “private ownership,” the CBO report stated, essentially kept it off-budget. Its entire board was appointed by the president with the advice and consent of the Senate. As its entire board was appointed by the president with the advice and consent of the Senate the “private company” label on Amtrak was at best tissue thin and far from reality.

The political fact was that the federal government has extensive control over’s Amtrak policies through its board of directors as well as through the leverage of its financial support. The legal status of Amtrak, and not the political reality, was what prospective bond buyers would want to examine. The “private” company status of Amtrak meant that the federal government would not be responsible for its obligations. Therefore, if Amtrak failed to repay the bonds, the federal government would not be liable,

and this would affect the yield on the bonds. Investors who assumed that Congress would enact legislation to authorize repayment of Amtrak bonds were taking a risk. With federal backing, investors would consider Amtrak bonds to be about as good as Treasury bonds and would be willing to pay a premium for them.

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See Also: High Speed Rail, Design and Technology of; High Speed Rail, Policy and Planning of; High Speed Rail, Safety Issues of; National Railroad Passenger Corporation/Amtrak.

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Highway Aesthetics

Highways are traditionally and primarily built to be functional. They are an infrastructure that supports travel, is designed by engineers, and is concerned with matters such as network, navigability, and safety. At first sight, this utilitarian perspective leaves little room for any aesthetic sensitivity. However, the history of highway beautification in the United States dates back to the beginning of the 20th century.

In broad terms, highway beautification concerns the projects or actions for the conservation, enhancement, and/or stabilization of the roadside landscape. It is relevant for the study of transportation modes and infrastructures from the public policy point of view because it is intrinsically associated with issues of safety, of environmental and ecological sustainability, and of economic efficiency. It concerns not only short-range operations but also long-range planning.

Early Stages

In the first couple of decades of the 20th century, the first American parkways were constructed near the Bronx River in New York City as a greenbelt that would prevent pollution and erosion. All infrastructures surrounding these recreational roads had to comply with specific aesthetic standards. From then onward, and despite the proliferation of parkways for recreational use and commuter routes, issues concerning aesthetic sensitivity remained on the agenda, and in the 1930s some major road projects even incorporated landscape architects.

The American Association of State Highway and Transportation Officials (AASHTO) in 1930 adopted a resolution on roadside beautification. It addressed the conservation and enhancement of roadside plants, the beautification of town entrances, the creation of parks and rest areas, etc. In order to promote a more enjoyable use of roadways, it advocated the harmonious integration of landscape design, architecture, and engineering in the process of road planning.

However, during the 1940s and 1950s, the construction of roadways increasingly ignored the most basic environmental and aesthetic principles. The construction of the Dwight D. Eisenhower National System of Interstate and Defense Highways, also known as the Interstate Highway System, began in 1956, and the environmental and aesthetic disruption it originated became clear in the following decade.

Highway Beautification Act

The Bonus Act, adopted in 1958, was the first American legislation to encourage states to control outdoor advertising in the vicinity of the Interstate Highway System. It was a voluntary program that states could join, based on an agreement with the federal government in order to control outdoor advertising and thereby be eligible for a bonus payment.

The first major piece of national legislation with an environmental focus was the Highway Beautification Act. It followed President Lyndon B. Johnson's Great Society legislative agenda. The intention to beautify the country's highways was one of the first steps to improve the overall standards of quality of life in the United States. The Highway Beautification Act was adopted in 1965, against the backdrop of the "freeway revolts" of the 1960s, which focused on the potential negative impact of

highways in urban areas. At that time, public opinion emphasized the need to harmonize highways with their surrounding landscape, infrastructure, and historical sites.

The Highway Beautification Act called for control of outdoor advertising. This was to include the withdrawal of specific types of signs existing alongside the growing Interstate Highway System and the primary highway system. It also required the junkyards neighboring the interstate or primary highways to be either removed or screened. Finally, it clearly encouraged scenic enhancement and roadside development.

The act exempted direction and other official signs, on-premise and for sale or lease signs, and signs in zoned commercial and industrial areas. New signs to be erected were supposed to comply with specific size, spacing, height, and lighting criteria, and a just financial compensation was to be provided for the removal of previously legal billboards. In sum, a tremendous effort to harmonize

the image of the Interstate Highway System was being put in place.

However, the Highway Beautification Act has been no stranger to controversy. Some studies suggest that there are fewer billboards now than when it was enacted. Other studies suggest the opposite, considering the act to be a regulatory failure, because it has not succeeded in removing existing billboard clutter or preventing its spread. Some studies go so far as to state that during the past decades the Highway Beautification Act has all but been completely transformed into a sign industry-dominated program.

These studies claim that the act is in fact subsidizing the very industry it was meant to regulate by shielding it from the desire of state and local governments to implement effective control of the billboard issue. It is a fact that many legislative proposals to revoke or alter the act have been supported by the same environmental organizations that previously championed it, while the billboard industry



This stretch of Route 66 running through Missouri in 1953 was lined with billboards advertising commercial products and area businesses. The Highway Beautification Act, adopted in 1965, was the first major piece of national legislation with an environmental focus. Supported by growing public sentiment against highway advertising at the time, the intention was to beautify the country's highways as a first step toward improving overall quality of life in the United States.

has become one of its advocates. Besides its ineffectiveness in controlling the erection of new billboards along roadways, it has been used as validation for vegetation control, which in many cases is criticized for simply destroying vegetation located in the right-of-way in front of billboards.

Despite the fact that the primary objective of the Highway Beautification Act was to control the spread of billboards, a shift in public opinion revealed that a growing number of people considered billboards to be a good way to contribute to the safety and enjoyability of highways. While some still consider billboards to be ugly and intrusive, harming scenic beauty and bringing nothing of value, others perceive them to be interesting and potentially informative—useful to travelers. Billboards are also deemed to be able to create jobs and to help businesses attract customers. Studies conducted across the past four decades tend to confirm that the American public favors billboards, considering that their benefits outweigh any potential costs. Moreover, the support for a ban on billboards has been decreasing since the 1990s.

Twenty-First Century Challenges

At the turn of the century the issue of roadway aesthetics was firmly back on the agenda, as illustrated by the Transportation Equity Act for the 21st Century of 1998. The latter followed a decade-long process that began with the Intermodal Surface Transportation Act and the National Scenic Byways program, both of 1991. These aimed to protect and beautify both highways and roadways that were noted for their scenic, natural, historic, cultural, archaeological, or recreational quality. The concept of roadway aesthetics had now broadened to encompass both the Interstate Highway System and the network of less-traveled roads.

The concept of highway aesthetics not only returned to the policy agenda but also widened in scope, becoming much more than the plain control of outdoor advertising and other forms of visual pollution. For example, the Safe, Accountable, Flexible, Efficient Transportation Equity Act of 2005 was intended, among other things, to protect and enhance the environment, promote energy conservation, improve the quality of life, and promote consistency among transportation improvements and state and local planned growth and economic development patterns.

Alongside basic programs focused simply on the regular picking up of litter on roadsides, there can now be found new integrated functional policies that tend to focus on three groups of objectives: environmental sustainability, economic impact, and safety.

Environmental sustainability. There are programs implemented throughout the United States that aim to protect and enhance the natural roadside growth and forestry through focus on tree care and planting, land management, and soil and water quality. Roadside landscape projects can also become proactive tools to help manage stormwater, filter air, abate noise, conserve energy, and provide wildlife habitat.

Economic impact. Economic dividends may result from making a city or region a more attractive place to visitors and businesses. This can be achieved through techniques that create visual impact and a distinctive sense of place. The overall goal is to create a specific first impression and a lasting one. Roadside landscape is central to highway travel experiences, which in turn play a significant role in the perceived attractiveness of the places where people live, work, and visit. In this sense, highway beautification can be a profitable investment with positive returns.

Additional economic dividends may result from integrating different functions, besides transportation, throughout the network of highways. A series of facilities, such as sightseeing platforms, parking lots, toll plazas, traffic administration facilities, etc., may have a significant role to play in local tourism strategies, and in the direct or indirect creation of employment.

Safety. Some studies have suggested that beautified or scenic highways are also safer highways. The causal relation between highway aesthetics and safety derives from the fact that many elements used in beautification programs simultaneously contribute to safer traveling, for example, better lighting, less litter, controlled vegetation, places to stop and rest, etc. In addition, one tends to drive slower when the highway experience is more enjoyable.

This new integrated policy approach requires added care in terms of the planning, design, construction, and management of highway beautification programs. Three key issues stand out:

Context sensitive design. Highway beautification programs should be context sensitive. In other words, they should be site specific and take into consideration the communities and places where they are implemented.

Integrated approach. The Transportation Equity Act for the 21st Century called for an integrated approach to highway planning and design process that should include not only civil engineers but also architects, landscape architects, and urban designers. Highway beautification programs should build on multidisciplinary teams, interagency collaboration and public-private partnerships. They should be planned and designed in cooperation with other programs, such as those regarding drainage and maintenance, accessibility and transit, pedestrian and cyclist routes, safety, etc. A fundamental measure is to develop a monitoring and evaluation system to help track the costs of the programs, and their accomplishments.

Beautification as a long-term strategy. Those who defend the benefits of highway beautification programs agree that highway aesthetics should be a factor not only in short-range management operations but also in long-range public policy and planning.

In other words, in order to achieve its full potential highway beautification should be integrated not only into road maintenance procedures but also into the public policy processes of planning, design, and construction of roadways.

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See Also: Highway and Road Safety; Highway Construction and Maintenance; Highway Landscaping; Highway Planning; Road Signage; Scenic Roads and Parkways; Visual Pollution.

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Highway and Road Safety

Highways and roads are one of the major factors in loss of life and serious injuries globally. According to the World Health Organization (WHO), approximately 1.3 million people die each year on the world's roads, and between 20 and 50 million more sustain nonfatal injuries. Road safety is a very difficult problem to address. While education and engineering may improve road safety in the long term, successful campaigns and effective enforcement may lead to quicker reductions in injuries and fatalities.

A basic concept in road safety is that the number of fatalities is a function of the road risk and the level of exposure of road users (to this risk). This implies that in order to reduce the level of fatalities, one needs to attempt to reduce the risk of traveling. Furthermore, when the exposure of the population to this risk is limited, then the overall number of fatalities is reduced.

The WHO Global Status Report on Road Safety 2013 provides an excellent overview of the current state of affairs in road safety globally. Road crashes are considered by the WHO to be a global health epidemic, and they are the leading cause of death for young people (aged 15 to 29). If current trends persist, by 2030 road traffic accidents will be the fifth-leading cause of death. While a significant number of countries (88, with a population of 1.6 billion people) managed to reduce road crash fatalities between 2007 and 2010, 87 other countries experienced increases of road traffic crashes during the same period. As expected, the higher road traffic fatality rates are found in middle-income countries, particularly the African region, where there is increasing motorization but poor road infrastructure, vehicle condition, and traffic education.

In the United States, over 34,000 people were killed in traffic crashes in 2012, a small increase over the low numbers in 2009–11, but a significant

reduction from the peak fatalities that exceeded 51,000 per year in the late 1970s. In 2011, approximately 30,100 people were killed in the European Union of 27 countries (EU27) as a consequence of road crashes. During the period from 2002 to 2011 in Europe, road fatalities decreased by almost 44 percent. Nine European countries achieved a reduction of more than 50 percent in the period 2001–11.

Traffic crashes are associated with a wide range of negative impacts, ranging from direct to indirect. The actions that can be used to reduce the number and severity (and therefore impact) of road crashes are often associated with economic costs. In order to evaluate whether a countermeasure should be used—or alternatively, which specific countermeasure to use—one needs to perform a cost–benefit analysis. In order to be able to do that, both “sides of the equation” need to be expressed in the same unit, usually monetary units. One of the parts of this equation that is most difficult to convert to monetary values is traffic fatalities.

Vulnerable Road Users

The drop in fatalities of motorized vehicle occupants in the more advanced (from a road safety point of view) countries in the world has turned attention to some of the more vulnerable groups of road users. In terms of mode of transport, vulnerable road users include pedestrians, bicyclists, and power-two-wheeler (PTW) riders; in terms of age groups, children and older travelers are particularly of interest.

Pedestrians are among the most vulnerable road users, accounting for 22 percent of all traffic fatalities, and the largest share of these are 65 years old or older. The WHO is calling on governments to take concrete actions to improve the safety of pedestrians. Children are particularly vulnerable. Each year, more than 800 children under the age of 15 are killed on European roads and 100,000 are injured.

According to the National Highway Traffic Safety Administration (NHTSA), in the United States, for example, despite the continuous decline in automobile fatalities, motorcycle deaths have increased every year between 1998 and 2011 (except in 2009 when there was a 16 percent decline). In 2011 4,612 motorcyclists died on U.S. roads, a 2 percent increase over those killed in 2010. Motorcyclist fatalities’ contribution is disproportionately high, as they are 14 percent of total highway fatalities, although motorcycle registrations are only 3

percent of total vehicle registrations. Safety analyses suggest that on a per-vehicle-kilometer basis, motorcyclists are 30 times more likely to die in a crash than car occupants, and five times more likely to be injured.

Addressing Road Safety

Road safety is a very difficult problem to address, as it incorporates a diverse group of factors and stakeholders that need to cooperate. While education and engineering may improve road safety in the long term, successful campaigns and effective enforcement may lead to quicker reductions in injuries and fatalities.

The risk of road travel can be reduced by infrastructure improvements, paying special attention to vulnerable road users, mitigation of distraction, and increased enforcement. Reduction of exposure can be the result of policies and also a result of exogenous factors, such as a recession, which restricts the ability of people to travel by car, or unemployment, which reduces the need to travel.

The assessment and improvement of road safety requires a large effort of data collection and analysis. A number of national and international organizations collect and aggregate road safety data, either at a global level, such as the Organisation for Economic Co-operation and Development (OECD) International Transport Forum (ITF) International Road Traffic and Accident Database (IRTAD), or at a regional or national level, such as the European Road Safety Observatory (ERSO).

The task of harmonizing road safety data into a larger database becomes particularly complicated because of differences in the way that data are collected and organized at each individual region. Even for seemingly simple concepts, such as that of a road crash fatality, different definitions (for example, counting those who die within 24 hours from the occurrence of the crash versus counting those who die within 30 days from the crash, which is the recommended approach) result in data that may not be directly comparable across regions. Common definitions are being developed and applied gradually, but they require change of procedures, which sometimes is very hard to implement in the field.

A related issue is that of underreporting, that is, the number of fatalities recorded by hospitals is consistently higher than that provided by the police (police are the source of traffic fatality data in the

majority—71 percent—of countries). It is more difficult for police to follow up on the outcome of traffic crash victims, suggesting that when data come from the police, underreporting tends to be higher than when data come from the health sector. While there are approaches to correct for this issue, the problem of incomplete data affects the quality of road safety monitoring programs.

Infrastructure Improvements

Inadequate and poorly maintained road infrastructure is often a contributory factor to traffic crashes. The severity of incidents may also be higher due to inappropriate road environment. For example, in a road without appropriate safety barriers or median, accidents may result in more severe injuries. Road safety audits and road safety inspections provide an important instrument in improving the safety of roads, both during the design and construction phases and during operation. These activities are undertaken by experienced, certified road safety engineers who identify limitations in the design or maintenance of the road so that they can be fixed in time.

Self-explaining roads and forgiving road infrastructure are two modern highway design concepts that aim to considerably improve road safety from an infrastructure point of view. The concept of self-explaining roads suggests that the roadway design should communicate to the drivers the appropriate driving patterns (for example, speed, headway, level of awareness) without the need for explicit signing. Therefore, the driver will be able to instinctively adopt an appropriate driving behavior for each roadway, thus limiting inappropriate driving conditions that could result in traffic crashes.

The concept of forgiving roads suggests that even when an accident does occur, the road design should provide the necessary safety elements (for example, safety barriers and median) to minimize the impact to the involved vehicles, drivers, and passengers and to the traffic (thus minimizing the danger for secondary incidents, which are often even more severe than primary incidents).

Monitoring and assessment of road condition is a very difficult task that is, however, essential to maintaining a safe road network. Not unlike the star ratings that are assigned to vehicles based on crash tests by EuroNCAP in Europe or NHTSA in the United States, organizations such as the

International Road Assessment Programme (iRAP), EuroRAP, and others offer road assessment programs. These programs inspect high-risk roads and develop Star Ratings and Safer Roads Investment Plans; provide training, technology, and support to authorities and road managers; and track road safety performance.

Distraction

Distraction has received considerable attention over the last few years as a leading cause of traffic crashes. The emergence of in-vehicle devices (for example, entertainment centers, in-dash navigation devices), as well as nomadic devices (for example, smartphones, tablets, personal navigation devices) offer an increasing amount of distracting visual and acoustic stimuli to the drivers. Furthermore, digital billboards and signs with pulsing, vivid lights contribute to a distracting road environment, potentially confusing the driver. Considering that the reaction window available to the driver in case of emergency is very small, it is evident that all these distractions can diminish the driver's ability to respond effectively to a dangerous situation and avoid the crash.

Vehicle, system, and device manufacturers and integrators are proposing alternative user interfaces that limit the need for drivers to take their eyes off the road; however, it is important to also consider the cognitive burden on drivers by responding to messages or queries by the systems.

There are three basic types of distraction: visual, cognitive, and manual. Often, a driver is distracted by a combination of these. However, distraction is not only related to technology or driving-related tasks. Talking with passengers in the car, smoking, or eating are also significant distractions. Most such distractions can be easily avoided by better organization and planning of activities by the driver.

Financial Conditions and Road Safety

Financial crisis and recession can lead to reductions in exposure to traffic risk due to a number of phenomena. (During the 2008 recession, the United States reached record low road crash fatality numbers, which were comparable to those in the 1960s.) Increased fuel prices, decrease of recreation mobility, and less heavy-goods vehicle traffic are some of the reasons that contribute to this temporary reduction in exposure. Higher

unemployment may lead to less need for travel and a reduction of risky driving.

As young people are usually most seriously hit by unemployment, this means that the more dangerous segment of the population (due to not only lack of experience, but also attitudinal and behavioral characteristics) do not travel as much, as fewer of them may afford vehicle ownership and travel. Finally, travelers may consider switching from car to public transport, which is, in general, safer.

While these factors are expected to have a positive effect on road safety, there are a number of competing factors. For example, dire financial situations may force travelers to shift modes from (less affordable) private car to walking, bicycles, and motorcycles. These latter modes, however, have a considerably higher risk associated with them. Furthermore, lower maintenance of vehicles may lead to some breakdowns or accidents, while poor road conditions may contribute to some crashes as well. The behavior of the drivers may also become more erratic, as they might transfer their financial problems to the road.

It is important to consider these effects when evaluating overall road safety levels, because such reductions that are not related to inherent road safety improvements will be countered once financial conditions improve and most people switch back to using the automobile more.

Traffic Law Enforcement

Traffic violations are a significant contributing factor to traffic crashes and fatalities. Enforcement is a means to prevent collisions from happening by way of persuading drivers to comply with the safety rules. Deterrence is based on giving drivers the feeling that they run too high a risk of being caught when breaking the rules.

The introduction of laws and regulations related to road safety has resulted in significant improvements in the level of road safety over time. Such examples include the introduction of seat belt, airbag, and ABS laws. Driving-under-the-influence control laws have also been implemented widely. For example, 111 countries (covering almost 70 percent of the global population) have comprehensive seat belt laws applicable to all vehicle occupants. Seat belts reduce the risk of a fatal injury by up to 50 percent for front seat occupants and up to 75 percent for rear seat occupants.

Enforcement is, of course, equally important, as laws may become inactive if accompanying effective enforcement strategies are not implemented. Traditional methods of police enforcement include roadside checks and the use of automated devices such as speed cameras. However, there are also technology-based approaches, such as alco-locks (in which a driver needs to breath into a breathalyzer before the vehicle may be started). Unlike infrastructure improvements, enforcement is a very cost-effective approach to improve road safety. Furthermore, traffic law enforcement is a measure that is usually supported by the general public.

Road Safety Initiatives and Campaigns

The increasing interest in road safety is being demonstrated by a large number of initiatives and campaigns aimed at improving road safety at a local, national, or international level. As motorization levels in less-developed (from a road safety point of view) countries increase, so are road crash fatalities expected to rise. The experience gained from countries that have applied successful strategies to improve their road safety level can be used to proactively improve the level of road safety in emerging countries and regions, thus saving large numbers of lives.

In 2010 the United Nations General Assembly unanimously adopted a resolution calling for a Decade of Action for Road Safety 2011–20, and for further Global Status Reports on road safety to monitor the impact of the program at national and global levels. The European Commission adopted a new target to halve road deaths by 2020 and, in its Transport White Paper in 2011, a “Vision Zero” for 2050. In order to achieve the 2020 target, the EU will have to surpass current reduction trends. To improve road safety, mass media campaigns have been widely used for decades. There is evidence that road safety campaigns can be effective, both for the general driver population and for special segments, such as professional drivers. One question that often arises is the degree of subtlety (or directness) that the campaigns should utilize in order to be effective.

Many policies and campaigns have been devised to sensitize people to road safety, aimed at shifting their perception and bringing this problem in the forefront of their consciousness. However, there are still vocal reactions that claim that shocking and scaring the public may not bring the desired results.

Besides the general public, road safety campaigns may be targeted at specific portions of the population, including professional drivers. Campaigns restricting the maximum time at the wheel for professional drivers, as well as laws prohibiting the transport of certain dangerous goods by road, include examples of such targeted campaigns.

Modeling Road Safety

Modeling road safety is a complex task that needs to consider both the quantifiable impact of specific parameters and the underlying trends that cannot always be measured or observed. The sensitivity of users to road safety campaigns, the improved quality of the vehicle fleet, the improvement of the driving skills of the general population, and the overall improvement of the condition of the road network are only some of the aspects that cannot be easily modeled directly. Therefore, modeling should consider both measurable parameters and the dimension of time, which embodies all remaining parameters.

Macroscopic modeling can provide insight into this problem and support policy makers in developing countries to adjust their policies in reaction to the changing macroscopic conditions.

For example, developing insight (regarding the expected breakpoints in road safety fatality trends, as identified from the developed countries time series) can be applied to performing more accurate future predictions for developing countries (which have still not reached the motorization levels of developed countries). Macroscopic, in this context, implies the analysis of aggregate (monthly or annual) accident and fatality data rather than the more detailed and disaggregate (in-depth) analysis of individual accidents. In-depth data can also provide very valuable insight about accident causation and contributing factors.

Although significant steps have been taken to improve road safety during the past decades (at least in the more developed countries, in terms of road safety), there are still several significant challenges that need to be addressed. Road safety statistics have traditionally focused on fatalities. While this is clearly a big part of the problem, serious injuries are also very important, as they often result in temporary or permanent disability.

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See Also: Automobile Accidents and Prevention; Automobile Design; Automobile Drivers, Elderly; Automobile Safety Inspections and Registration; Automobile Safety Systems; Bicycle Safety; Distracted Driving; Elderly Driver Safety Issues; Federal Automobile Safety Standards; Highway Safety Barriers and Traffic Barriers; Impaired Driving; Motorcycle Safety; National Highway Traffic Safety Administration; National Transportation Safety Board; Nonmotorized Vehicles, Safety Issues of; Pedestrian Safety; Pedestrian Safety, Blind and Elderly; School Bus Safety; Traffic Safety and Risk Assessment.

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Highway Construction and Maintenance

Modern road and highway construction in the United States follows a standard set of procedures for the entire process. Road construction design is the initial part of the process. A good design balances cost, safety, mobility, and social and environmental impacts. To achieve this balance, highway

designers use criteria that have been established through years of testing and research in the fields of highway engineering (including materials testing), traffic operations, and safety. Roadways and highways in the United States must comply with federal guidelines, even on state and local levels of construction. The U.S. Federal Highway Administration (FHWA) has adopted design standards for roadway geometrics, bridges and structures, erosion and sediment control, hydraulics, traffic noise, materials, and accessible pedestrian design. These standards apply to all projects involving the National Highway System (NHS). Design standards also apply to road maintenance, such as resurfacing, restoration, and rehabilitation (3R) projects.

The Process: Planning

The plan for the construction of a road or highway varies from one job to another and depends on (among other criteria) available financing, foundation and topography (environmental) conditions, nature of available materials and construction equipment, and the forecast for the type and volume of traffic for this particular roadway. Any road construction job consists of a number of basic steps, although, depending on the job, the relevant importance and the interaction among these steps will vary. These steps can be summarized as planning, programming, and preconstruction activities; site clearance; surveying and setting out; earthworks; bridge construction (if this applies); drainage structures; pavement construction; placement of road surfacing; placement of road furniture; and, landscaping.

A particular “document” read by many highway planners and engineers that is widely circulated and known as the basics of proper road planning is called “The Ten Commandments of a Good Road.” (The origin of this popular paper is a pamphlet printed at St. Michael’s College in Vermont in 1984.) It contains sage advice that is still passed around to those in the field of roadway or highway construction.

According to this paper, “The Ten Commandments of a Good Road” are the following: (1) get water away from the road, (2) build on a firm foundation, (3) use the best materials available, (4) compact all materials well, (5) design for winter maintenance, (6) build for traffic loads and volumes, (7) pave roads only when they are ready, (8) build from the

bottom up, (9) protect your investment, and (10) keep good records.

Preconstruction Activities

Before any building or construction can begin, a host of preparatory activities must take place at the construction site. These include surveying, setting out of stakes, site clearing, and site layout. Site-based management can significantly improve cost and time savings during the construction process without requiring much additional work. Site management involves many tasks, including site investigation before the construction process begins, material procurement and delivery, systematic performance monitoring, information collection, maintenance of site records, and communication among various responsible parties involved. Construction site layout involves identifying, sizing, and placing temporary facilities within the boundaries of the construction site. These may range from simple lay-down areas to warehouses, fabrication shops, maintenance shops, and residence facilities.

Earthwork

Earthwork is one of the major components of road construction. It is also one of the most important, as it literally lays the foundation for the road. Without adequate support, a road will deteriorate rapidly. A good road requires a suitable foundation composed of stable material, because the road base determines the service life of a road. The earthwork process includes excavation, material removal, filling, compaction, and construction. Moisture content must be controlled, and compaction is done according to standard design procedures. The eventual aim of the earthworks phase of construction is to position the subgrade underlying the pavement layers in the right location and at the correct level, and to provide drainage.

Some of the operations involve creating cuttings by excavating through high ground, formation of embankments by filling over low ground, shaping the finished surface to design levels, and excavating for drainage systems. A typical sequence of operations is the cut, which is excavation to the depth necessary to reach the formation level; transportation of any undesirable materials away from the site; suitable disposition of any excess cut material; and hauling suitable materials from cuts to fill areas. Next in the sequence is the fill, which

is drainage of water from depressions and disposal of any unsuitable underlying material; spreading of fill material in horizontal layers to the required thickness (usually not more than 250 millimeters); and thorough compaction of these layers to required the density.

In the process of filling a depression to reach the road level, the original bed is flattened after the removal of the topsoil. The fill layer is distributed and compacted to the design specifications. This procedure is repeated until the desired compaction is attained. The fill material should not contain organic elements, and should possess a low index of plasticity. Fill material can include gravel and decomposed rocks of a particular size but should not contain huge lumps of clay. Sand clay can be used. The area is considered to be adequately compacted when the roller movement does not create a noticeable deformation.

Drainage Structures

The importance of drainage cannot be overemphasized in road construction and maintenance.



Construction workers lay down a 4-inch warm mixed asphalt base layer before adding a top layer of material during a Federal Highway Administration project in Texas in 2011.

Storm drainage and ecological concerns must be considered seriously. Sediments and erosion need to be controlled to avoid damaging effects. Drainage systems must be constructed so that they are able to carry storm- and wastewater to a waterway, stream, or river, and eventually to the sea. Water affects the entire serviceability of a road. Too much water in the base and subgrade materials weakens the road. Water allowed to remain on top of a road weakens the surface and causes potholes and cracking. Water can saturate the base, erode slopes and ditches, ruin road surface and shoulders, and, during the freeze–thaw cycle, destroy the entire road structure.

A well-engineered surface drainage design is the best way to lessen water damage on a road and to lessen future maintenance costs. Proper surface drainage prevents water from infiltrating the pavement surface and removes water from the driving lanes to side ditches, which carry the water away from the road. A surface drainage system has four main components:

- **Road crown:** The road crown allows surface water to run into the side ditches.
- **Shoulders:** Shoulders are an extension of the road surface and allow for the passage of surface water to the ditches.
- **Ditches:** Ditches are used to carry water away from the roadway. Water collected and carried to the ditch has to be directed away from the roadway at frequent intervals, sometimes using a culvert.
- **Culverts:** Culverts usually channel water from one side of the road to the other, helping control the flow of water and slowing it down to reduce erosion.

Pavement

Three main types of pavement are used in roadway and highway construction: gravel and crushed rock pavement, asphalt pavement, and Portland cement concrete pavement (PCC). PCC is the most commonly used road material in the United States. For highways, the general pavement construction procedure involves placement, consolidation, finishing, curing, and jointing in rapid succession.

Placement involves any equipment or procedures used to place the delivered PCC on the desired surface at the desired thickness. During the screeding

(or strikeoff) process, excess portions of the roughly placed PCC are cut off in order to bring the slab to the required elevation. This is usually done by dragging a straightedge across the slab at the required elevation. Consolidation involves any means used to eliminate undesirable voids. This is typically accomplished with the use of vibrating machines.

Finishing involves any equipment or procedures used to impart desirable surface characteristics. Generally, finishing can be divided into floating and texturing. Curing is the maintenance of satisfactory moisture and temperature in PCC as it sets and hardens such that the desired properties can develop, and jointing involves all those actions used to insert purposeful discontinuities in the pavement and to seal them appropriately.

For most of the 20th century, the same materials—Portland cement, high-quality aggregate, and water—were used in pavement concrete, with only minor changes. In the past two decades, the industry has experienced more changes than those that occurred in the previous 80 years due to changes in road use, availability of materials, environmental issues, policy, and financing. In order to meet these growing demands on highway construction and rehabilitation, several joint projects between cement companies and the FHWA have been researching new materials and processes for highway pavement construction.

Road Surfacing

The surface course is the layer in contact with traffic loads and normally contains the highest quality materials. It provides characteristics such as friction, smoothness, noise control, rut and shoving resistance, and drainage. In addition, it serves to prevent the entrance of excessive quantities of surface water into the underlying base, subbase and subgrade. Road surfacing materials may be gravel, sprayed bituminous seal, asphalt, or cement concrete.

This top structural layer of material is sometimes subdivided into two layers, the wearing course and the intermediate/binder course. The wearing course is the layer in direct contact with traffic loads. It is meant to take the brunt of traffic wear and can be removed and replaced as it becomes worn. The intermediate/binder course is the layer that provides the bulk of the hot mixed asphalt (HMA) structure. Its chief purpose is to distribute load.

Road Furniture

“Road furniture” is the term used in reference to pieces of equipment installed either after a road or highway is complete or toward the completion of construction. These items include structures such as light signals, traffic signs, street lights, fire hydrants, transit stops, and community amenities such as benches, waste containers, water fountains, and restrooms. Some roadways and highways are designed to incorporate memorials or local artwork such as sculpture and murals. Road furniture is not just an afterthought. The ideas should be in place in the initial planning phase; in fact, some of these components are integral and necessary parts of the entire infrastructure.

Landscaping

Landscaping is considered a major element in highway design, as its effects are far reaching. Four components that for decades have been a part of what is referred to as “the complete highway” are utility, safety, beauty, and economy. These ideals are intertwined and may all be realized through landscape planning and design. Among many benefits to a roadway, landscaping helps enhance the mobility of people and goods, encourages economic prosperity, and preserves the quality of the environment and communities. It is a major consideration in smart growth planning and development policies.

Highway Preservation and Maintenance

The American Association of State Highway and Transportation Officials (AASHTO) defines preventive maintenance as “the planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system without increasing structural capacity.” Preventive maintenance activities are those that address aging, oxidation, surface deterioration, and normal wear and tear from day-to-day performance and environmental conditions. Preventive maintenance activities extend the service life of the roadway asset or facility in a cost-effective manner.

Timely preventive maintenance and preservation activities are necessary to ensure proper performance of the transportation infrastructure. A 1997 report to Congress titled “Status of the Nation’s Surface Transportation System: Condition and Performance” warned that more than 48 percent of the

nation's rural interstate highways and nearly 60 percent of urban interstate highways have pavements rated fair to poor. From these numbers, it is evident that the condition of the U.S. highway infrastructure has been deteriorating. Yet the demands on the U.S. transportation infrastructure are greater than ever.

Increasingly, state departments of transportation (DOTs) report that the proactive approach of preventive maintenance—instead of the typical strategy of fixing the worst first—cuts the need for costly, time-consuming reconstruction and rehabilitation projects while reducing associated traffic disruptions. Experience has shown that when properly applied, preventive maintenance is a cost-effective way of extending the service life of highway facilities. By using lower cost system preservation methods, local and state governments can improve system conditions, minimize road construction impacts on the traveling public, and better manage their resources needed for long-term improvements such as reconstruction or expansion.

Typically, regional offices work proactively with their State partners to establish a preservation component of planning, which is composed of various preventive maintenance activities and treatments. These include roadway projects such as joint repair, seal coats, pavement patching, thin overlays, shoulder repair, restoration of drainage systems, and bridge activities such as crack sealing, joint repair, seismic retrofit, scour countermeasures, and painting. Other activities that at one time were considered routine maintenance may now be considered as preventive maintenance (extending service life). These can include such work items as regional projects for periodic sign face cleaning, cleaning of drainage facilities, corrosion protection, and spray-applied sealant for bridge parapets and piers.

Planning

State DOTs utilize maintenance management systems to collect data from surveys, inventories, and inspections, to prepare roadway conditions assessments, and to manage highway infrastructure assets, accordingly. Core assets that should be addressed are pavements, bridges, tunnels, stormwater systems, and appurtenant facilities. Additional assets that may be included are shoulder/sidewalks, slopes, rock-fall, slope protection, and vegetation.

Some state DOTs use a roadway characteristics inventory (RCI) to track their roadway assets to

plan for their maintenance and repair. Many DOTs conduct RCIs on an annual basis to update and maintain their data relative to these assets. These inventories typically include hundreds of infrastructure features or characteristics organized into various categories, for example, types of guardrails or fencing. The inventory will take into account the amount (or mileage) of an asset, rate the existing quality of parts of the structure, and determine the level of maintenance required.

One of the more challenging aspects of designing a conditions assessment is selecting the performance characteristics or criteria that will be used to rate each asset. For example, guardrail repairs are performed to keep the guardrails functioning as intended. Therefore, the percent of guardrails that are functioning as intended might be used as a performance criteria. Another example would be culverts, using the attributes of clogged flow, interrupted flow, and structural deterioration.

More recently, there has been a push to integrate the concept of sustainable highway systems that take into account environmental, economic, and social equity dimensions in addition to fulfilling the functional needs of transportation. Preventative maintenance must take into account recycling and reuse of materials, vegetation management, and environmental impacts, among other components, while developing asset management. For sustainability to be fully integrated into highway programs, it must be considered throughout the project lifecycle, from planning through operations and maintenance.

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See Also: Bridges; Environmental Impacts; Highway Aesthetics; Highway Design and Engineering; Highway Landscaping; Highway Planning; Interstate Highway System; Planning, Programming, and Budgeting Systems; Water Pollution.

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Highway Design and Engineering

The art and science of highway design and engineering has been constantly evolving since ancient times. Notably, the Roman Empire connected and policed its sprawling provinces and colonies by means of well-constructed roads, causeways, bridges, and viaducts—many of which have lasted millennia and are still in everyday use by today's wheeled vehicles. These thoroughfares might not have lasted so long had it not been for the salient fact that the hands-on, materials-science knowledge of those Roman builders and craftsmen was matched by the administrative energy and expertise of the specifiers, engineers, and designers. Every mile of every road had to be surveyed and laid out in a certain way and then built and maintained under a very specific regimen.

In the modern era, the designers and engineers of highway networks may be excused for sometimes thinking that there are more "bureaucrats" than warranted. Even though the highway systems of the world carry billions of passengers and vast tonnage of goods to all but the most remote areas of the inhabited world, it may seem that no stretch of road is beyond the reach of lawmakers

and policy administrators with a burning desire to tweak, amend, update, change, and challenge the existing ways and means of highway construction.

Yet there are very sound reasons—practical, moral, social, and professional—for this state of affairs. The dramatic results in the decline of traffic fatalities is one of the more obvious justifications for maintaining comprehensive and up-to-date codes and enforcement of highway layout and building methods, and an inducement for authorities to continue funding improvements quite generously within policy guidelines. In the United States, for example, according to data compiled by the National Highway Traffic Safety Administration (NHTSA), the number of fatalities per 100 million vehicle miles traveled (VMT) was cut from 5.06 fatalities/VMT in 1960 to 1.11 in 2010. Components of this drop included: better driver education, better automotive safety technology, more aggressive enforcement of anti-driving-while-impaired (specifically targeting alcohol) laws, and improved highway design and construction practices.

Strategic Plans and Funding

In seeking advanced solutions for improved roadway design, highway engineers can call upon a diverse and sophisticated body of research and design recommendations. They also can partner with transportation authorities in various jurisdictions to develop plans to avail themselves of funding sources specifically earmarked for these adaptive highway design options. As one example, the Transportation Research Board (TRB), an institutional component of the National Academies, joined with the American Association of State Highway and Transportation Officials (AASHTO) standing committee on highway traffic safety as well as the Federal Highway Administration and the NHTSA in a 1997 initiative to study ways and means of improving safety on American highways. Among the 22 focus areas identified were several that addressed roadway infrastructure design and engineering. The study led to pooled funding that was administered under the new AASHTO Strategic Highway Safety Plan.

This plan has been updated periodically with fresh research results, recommendations, and funding availability for implementation. For example, in 2003 the National Cooperative Highway Research Program (NCHRP) issued an exhaustive report on unsignalized intersection accidents that included

highway architectural and engineering concepts shown by evidence to prevent such accidents and significantly reduce the severity of those accidents that still might occur. Among the ideals were traffic calming, improved management of access near such intersections by means of roadway architecture and geometric design improvements, adaptations to yield better sight distance, and installation of such supportive features as splitter islands, stop bars, rumble strips, warning signs, flashing beacons, and improved maintenance of signs and other features.

The report enumerated a range of expected costs—covering material, equipment, and personnel—for everything from restriping pavement areas to road-widening projects. Public information and awareness programs were emphasized as an ancillary cost driver, but one that would yield higher benefit return, especially when reengineering projects first come on line. Administrative costs, too, were considered, as changes of policy, design guidelines, and criteria are seen as core attributes of a functioning mitigation program.

The report also pointed to a range of potential funding sources, from private-property owners to specific local, state, and federal highway agencies. AASHTO and NCHRP emphasized that priorities and goals vary widely from state to state, and it is under these priorities and policies that highway designers and engineers must operate. It is also within the understanding of this context that engineers should team with their policy-making and administrative authorities when preparing funding requests. For example, the agencies pointed to the variance in traffic incident reduction goals of several states within the same general time frame of 2002–05. The goals varied not only quantitatively but by qualitative measure as well. Pennsylvania sought to cut fatalities by 10 percent, while California adopted a 40 percent fatality reduction goal, as well as a 15 percent cut in injury-causing collisions and a 10 percent cut in work zone crashes.

Among the more extensive, state-based highway design resources is that administered by California, through its Caltrans department. With rules covering everything from computer-aided design standards to storm water collection and dissipation engineering methods, and with a served population exceeding 30 million, Caltrans regularly issues Design Information Bulletins that address such topics as freeway interchange safety improvements; public

boat launch access ramps; culvert repair practices; material disposal, staging, and borrow siting; and capital preventive maintenance guidelines. Each of these subject areas anticipates and incorporates public hearing processes and policies.

Layout Fundamentals

Much of highway design stems directly from safety concerns, and the predominant factor in much of the inherent safety level of any segment of roadway derives from issues of visibility. Allowing for specified traffic volume, access, and speed requirements, designers must integrate carefully calibrated line of sight, sight distance, lane alignment, and accommodation of anticipated nonroadway visual elements, such as the natural setting and the built environment. There are also standards for roadway cross-section, clearances, grade, alignment, lane width, curve radius, acceleration and deceleration areas, and shoulder width. With the expansion of bicycle traffic beyond urban areas to highways, especially at choke points such as bridges and overpasses, the incorporation of safe bicycle and pedestrian lanes and barriers are an additional area of engineering and rulemaking.

A variety of solutions can be offered for material specifications, with the most fundamental decision being whether the road will be surfaced with a pavement derived from asphalt or from concrete. Another fundamental is the choice of rigid or flexible pavement, each of which has advantages and drawbacks in terms of service life, pavement fatigue and distress, friction quotient, vulnerability to development of roughness, and permeability. The layout starts with surveying—but it does not end at the side of the road. Today more than ever, legal requirements to protect and support specified levels of environmental integrity and human community quality of life mean that designers must generate plans to satisfy policy standards by local and state jurisdictions for noise abatement, visual wholeness, community cultural significance, water runoff, erosion control and stormwater overflow mitigation, and related criteria.

Driver Behavior Factors

Many fundamentals of highway engineering have a design basis that may touch upon more complex interactions than at first appear possible. The importance of the highway shoulder is one such apparently straightforward element that actually

can influence a host of seemingly nonrelated factors, especially driver behavior.

A road shoulder is often referred to as a “break-down lane.” That is one designed-in function: to provide a relatively safer area for motorists in distress to pull off the main traffic lanes until assistance can arrive or quick repair can be accomplished. However, the shoulder of a highway also provides a deeper psychological effect that can exert very real and very powerful physical forces on individual drivers and on traffic flow. It has been documented that on roadways that lack shoulders but do have instead a guardrail, wall, precipice, or other limiting physical barrier along the road boundary, many drivers tend to “cheat” their vehicles away from the outer boundary of the road, thus crowding toward the adjacent lane, whether traffic in that lane is moving with or against their own direction. This tendency, in turn, will in most cases cause prudent drivers to reduce speed—not necessarily the intent of the highway designer—and lead to greater congestion.

However, a large portion of drivers of a less steady nature may tend to weave between outer and inner lane boundaries; they may overreact, oversteer, and begin to precipitate real danger of loss of control or even collision. Even if an accident does not develop from such a situation, the capacity of the shoulder-less segment of highway has been effectively reduced. Again, this was likely opposite to the intent of the highway designer, but it is a result of failing to take into account the psychology, expectations, perceptions, and behavior of the driving public.

Every measure must be directed toward designing the highway to present the driver with overt, clear, visual, and mental cues that will direct his or her actions and decisions and “reward correct decisions” by meeting expectations in layout to which the prudent driving public has grown accustomed.

Maintaining Policy Goals

Highway design, surveying, construction, and maintenance practices impact many aspects of public policy in the sophisticated, highly interconnected world of today. In this context, the continually reviewed and improving policies and practices for proper highway engineering must meet local community, regional, and national criteria for public and private input as well as ever more challenging economic and environmental parameters. Budgetary factors of both the long-term capital investment

nature and the ongoing operational type underlie many decisions in highway engineering.

Due to this major fiduciary impact, and its municipal, state, and federal tax and revenue components, highway engineering will remain a core expense for the foreseeable future. It is also one that can only be properly approached and managed through cooperation and information sharing between the appropriate planning and operational agencies. By the same token, better coordination and improved policy-making practices can and do help deliver positive input to local and regional economies.

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See Also: Access Roads; Benefit–Cost Analysis of Transportation; Federal Aid Highway Program; Highway Finance; Intermodal Surface Transportation Efficiency Act; Light Pollution; Visual Pollution.

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Highway Finance

Following passage of the Federal Aid Road Act of 1916, highways and roads became an intergovernmental responsibility. Though the federal government has played the dominant role in setting nationwide highway priorities, states and localities have been involved in implementing policies, including financing and ownership of the roads and highways. The funds for highway construction, operation, and maintenance come from all levels of government—from bond sales and the general fund, in part, but mostly from a variety of highway user charges, including fuel and other excise taxes, tolls, and other user fees.

As summarized in Table 1, states collect the most own-source revenues for highways and roads (\$109 billion, or 49.3 percent of all highway revenues in 2010), followed by the federal government (\$59 billion, or 26.7 percent), and local governments (\$53 billion, or 24 percent). While the bulk of the revenue used to finance roads and highways comes from federal and state fuel taxes, other sources include various fees and sales taxes on automobiles, as well as tolls and bond proceeds.

Highway User Charges

Highway user charges are fees imposed primarily on highway vehicles, motor fuels, drivers, and other elements associated with highway and road use. The most common forms of user charges are tolls and fuel taxes, which levy charges that are roughly proportioned to the use of the road. A highway or road toll is a direct user fee charged for utilizing a particular road or highway facility.

The revenue derived from the toll is often used to cover the debt service incurred to design and build the road, bridge, or tunnel facility; to maintain and operate the facility; and to provide the basis for subsequent bond issues to finance facility improvements and expansions. For most states, toll financing has been undertaken on a project-by-project basis, rather than as an integral part of the states' financing strategy. In 2011, the 5,541 miles of toll roads, bridges, and tunnels generated approximately \$8.2 billion and \$2.5 billion for states and localities, respectively.

The federal government and the states levy fuel taxes on gasoline, diesel, and other special fuels. These taxes are levied as a flat rate per gallon and are collected from the refiner, manufacturer, or importer of the fuel and passed through the retailer to the highway user. At the state level, the average tax rate (weighted according to volume) on gasoline and diesel are 21.382 cents per gallon (cpg) and 21.338 cpg, respectively. The federal tax rate on gasoline is 18.4 cpg, and on diesel it is 24.4 cpg.

These fuel taxes are a category of highway-related excise tax. Other excise taxes include taxes imposed on tires, vehicle sales, and on the use of heavy vehicles. The federal excise tax on truck tires is an example of a highway-related excise tax. The premise for this tax is that trucks, because of their weight, cause much greater damage to roads and bridges, and the excise tax on their tires serves as a proxy for highway wear-and-tear charges.

At the federal level, the excise tax applies to tires purchased for vehicles with load capacity in excess of 3,500 pounds. The tax structure is somewhat proportional to the load capacity but may not

Table 1 Total receipts for highways (in billions and percentage of total) by government level

Year	Federal Government	State Governments	Local Governments
1950	\$0.50 (10.8%)	\$2.84 (61.6%)	\$1.27 (27.5%)
1960	\$3.06 (26.6%)	\$6.06 (52.7%)	\$2.37 (20.6%)
1970	\$6.14 (28.2%)	\$11.74 (54.0%)	\$3.87 (17.8%)
1980	\$9.83 (24.7%)	\$19.67 (49.5%)	\$10.22 (25.7%)
1990	\$14.43 (19.2%)	\$40.03 (53.2%)	\$20.84 (27.7%)
2000	\$30.82 (23.5%)	\$66.43 (50.7%)	\$33.86 (25.8%)
2010	\$58.95 (26.7%)	\$108.96 (49.3%)	\$53.07 (24.0%)

Source: Federal Highway Administration. "Highway Statistics 2010." <http://www.fhwa.dot.gov/policyinformation/statistics/2010>

cover all the costs imposed by trucks. While most states impose a tax on motor vehicle sales, this tax is typically not considered highway-related revenue because receipts are directed to the General Fund and not dedicated for highway spending. However, in some states, the motor vehicle sales tax is dedicated for transportation purposes.

Other highway user fees include a variety of fees associated with licenses, permits, and registrations. Interstate motor carriers, for example, purchase licenses, decals, or permits associated with the International Fuel Tax Agreement (IFTA) to operate in an IFTA jurisdiction. Vehicle registration fees, another example of user fees, are levied by every state on passenger and commercial vehicles. These fees are assessed according to various vehicle characteristics or combinations thereof, including a flat fee, by weight, by age, and by value. In some states, local governments may also collect highway revenues from vehicle registration fees.

Federal Highway Finance

At the federal level, highway finance is dominated by the gasoline tax. The federal government also imposes taxes on gasohol and other special fuels, but these provide minimal revenues. The Highway Trust Fund (HTF), which is the dedicated source of highway funds at the federal level, includes receipts from these and truck-related excise taxes. In 2011 the HTF revenue came from the following sources: diesel and special fuels tax (25 percent); gasoline (64 percent); and truck-related (8 percent). The truck-related taxes include three categories that impose taxes on heavier vehicles and their tires.

The tires tax, for example, increases from no tax on tires for vehicles with rated load capacity under 3,500 pounds to a tax of 9.45 cents for each 10 pounds over 3,500 pounds. The truck and trailer sales tax is 12 percent of the retailer's sales price for tractors and trucks over 33,000 pounds gross vehicle weight (gvw) and trailers over 26,000 pounds gvw. The heavy vehicle weight tax is an annual tax

Table 2 Sources of state and local revenues for highways

	2010	2005	2000	1995	1990	1985	1980
STATE REVENUES							
State general fund appropriations	4.7%	2.8%	4.5%	2.3%	3.3%	2.5%	5.2%
Federal funds	25.6%	23.9%	26.1%	27.9%	30.8%	30.7%	38.4%
Bond proceeds	18.6%	17.6%	9.9%	6.8%	7.1%	13.4%	4.1%
Roads and crossing tolls	5.1%	5.3%	5.1%	5.1%	5.8%	5.2%	5.6%
Motor fuels tax	19.6%	32.0%	38.2%	46.1%	60.6%	52.1%	57.4%
LOCAL REVENUES							
General fund appropriations	27.5%	29.5%	30.1%	26.2%	32.0%	28.6%	30.1%
Federal funds	1.7%	2.1%	2.1%	1.7%	2.6%	5.6%	7.7%
State funds	29.7%	23.8%	26.2%	28.1%	28.2%	23.9%	24.7%
Bond proceeds	9.6%	10.6%	7.1%	13.2%	8.3%	14.3%	9.5%
Roads and crossing tolls	2.1%	2.2%	1.8%	1.1%	0.6%	1.1%	0.6%
Property taxes, special assessments	18.7%	20.1%	19.3%	16.2%	18.0%	16.3%	17.5%
Local highway-user revenues (Motor fuel and motor vehicle tax revenues)	3.1%	3.5%	3.8%	3.4%	2.9%	2.0%	1.3%

Source: Federal Highway Administration. "Highway Statistics." <http://www.fhwa.dot.gov/policyinformation/statistics.cfm>

on trucks 55,000 pounds and over gvw—a tax of \$100 plus \$22 for each 1,000 pounds (or fraction thereof) in excess of 55,000 pounds (up to a maximum tax of \$550).

State and Local Highway Finance

User fees and bonds secured by highway user fees have been the predominant source of funds to finance highway improvements in most states since the early 1920s, but it was not until the Highway Revenue Act of 1956 (which created the HTF) that user charges (and the fuel tax, more specifically) became the major source of federal funds for highways. Local and state governments, through various mechanisms, receive fund transfers from the federal motor fuel taxes and other revenues, but they also pay for roads with other own-source revenues such as fuel taxes, road user fees, and general revenues.

Each state develops its own mix of fuel taxes and road user fees (often deposited into a dedicated Road Fund, which is equivalent to the federal Highway Trust Fund) and supplements it with federal funds, transfers of general revenues (not transportation related) from the General Fund, and other sources. In 2011, state gas taxes on gasoline varied from a low of 7.5 cpg in Georgia and 8 cpg in Alaska to a high of 37.5 cpg in Washington. The diesel tax similarly varied from 7.5 cpg in Georgia and 8 cpg in Alaska at the lower end to 46.2 cpg in Connecticut at the upper end.

Table 2 reveals the shifts in the sources of state funding for highways between 1980 and 2010. Federal funds dropped from 38.4 percent to 25.6 percent of total funding. Reliance on transfers from state General Funds have generally been less than 5 percent of revenues, while toll revenues have been fairly constant at just over 5 percent of total funding. Reliance on bonds has risen dramatically from 4.1 percent of revenues to 18.6 percent. The drop in the contributions of the fuel tax is precipitous—from 57.4 percent of total revenues in 1980 to 19.6 percent in 2010.

In contrast, a similar examination of sources of highway revenue for local governments exhibited a fairly stable trend over time. In 1980, appropriations from the General Fund composed 30.1 percent of total revenues for local governments. In 2010, this source composed 27.5 percent of total revenues. Local governments relied on 24.7

percent of their revenues from the state in 1980, compared to 29.7 percent in 2010. This increase in state funds compensated for the decline in federal funds from 7.7 percent in 1980 to 1.7 percent in 2010. Local highway-user revenues such as from the motor fuel tax and motor vehicle tax have consistently comprised less than 3 percent of total revenues. Bond proceeds were 9.5 percent and 9.6 percent of total revenues in 1980 and 2010, respectively.

Funding Shortfalls

The significant reliance at the federal and state levels on motor fuels tax revenues has resulted in highway funding shortfalls. One factor contributing to this shortage is well known—fuel tax revenues are declining as vehicles become more fuel efficient. According to data from the Bureau of Transportation Statistics, the average automobile fuel efficiency was 13.9 miles per gallon (mpg) in 1975, compared to 21.1 mpg and 22.6 mpg in 1995 and 2008, respectively.

In addition, states and localities now have a substantially larger highway/road system to maintain. Research by J.-E. Yusuf and L. O’Connell documents that lane miles of principal arterials have increased by more than a third between 1982 and 2007. When coupled with a large increase in construction costs and virtually no increase in the fuel tax rate (measured in real terms), this growth in mileage has resulted in lower revenues to finance construction, maintenance, and operations of highways and roads.

From 1982 to 2007, the Federal Highway Administration (FHWA) construction price index (adjusted for general inflation) rose 150.1 percent but the real gas tax rate (adjusted for general inflation) was almost identical in 1982 and 2007. Thus, the increase in vehicle fuel efficiency is but one of the problems confronting the states. They have more lane miles to maintain and the rise in construction cost has substantially outstripped the rise in fuel tax rates.

One obvious solution to addressing highway finance needs is to raise the motor fuels tax at the federal and state levels. Yet, in recent years few states have done so due to the lack of popularity of tax-raising measures. An alternative would be the adoption of a variable rate tax structure that would index the rate to some measure of inflation. This

would produce small but frequent (and more politically acceptable) rate adjustments.

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See Also: Highway Trust Fund; Motor Fuel Taxes; Vehicle Miles Taxation/Fees.

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Highway Interchange and Ramp Design

A highway interchange refers to the designed junction of two or more roads at different heights, or grade separation (essentially one road passes over another), that uses one or multiple ramps as a way to permit the freest possible flow of traffic involving the movement between roads. By maneuvering multiple lanes of traffic going in different directions, grade separation helps keep traffic flow at these crossroad sites moving efficiently and safely through a series of merges. Ideally, the highway interchange prevents traffic from at least one highway artery from having to directly cross any other traffic stream. Even if in an effort to help manage access traffic off the directional ramp or to maintain traffic flow on slip roads (short sections of roadways designed to move traffic to highways) traffic lights are installed, the traffic stream is only minimally

intruded. Highway interchanges are designed to handle capacity traffic and, in turn, to maximize the efficient movement of a massive volume of lane traffic at cross-purposes.

Because the interchange is such a routine part of highway navigation and surface transportation systems and because appreciating the design elements can require a familiarity with engineering design basics and a bird's-eye perspective above the roads themselves, drivers seldom appreciate the engineering that must go into the design of both interchanges and ramps. Nor do drivers recognize the sheer variety of conceptual models available to give transportation engineers a wide range of design options, as exchanges and ramp systems must account for conditions and variables including vehicular traffic flow and volume and type, topographical grades, the land-sprawl available for development, and even the weather (including wind and sun positions). Because vehicles must regularly (and safely) change not only direction but entire roadway systems, highway interchanges help create optimum transit conditions, although design features can create negative (and anxious) driving conditions, most notably manifested in lane jumping or weaving in which drivers must contest, often at high speeds, for access to appropriate turns. In general, however, interchanges make arterial traffic stream itself possible.

Most often highway interchanges connect freeways (controlled-access highways) or expressways (limited-access highways) with surface streets. Thus highway interchanges and ramps are ways to manage busy highways by allowing a full range of direction options to enter or exit in each direction. The design of highway interchanges and ramps is not only to maximize traffic flow but also to contain and direct it as well. For instance, heavy volume traffic trying to access highways can be controlled through the use of ramp meters, essentially street lights that modify access patterns to prevent clogging or accidents from careless access to busy highways.

Given the volume of vehicular traffic (in many urban areas more than 200,000 vehicles are accommodated on any single day) and the network of entangling roadways that now serve most metropolitan areas with over 50,000 populations, the design elements of highway interchanges must take into account the human factor in transportation systems. Confusion is easy

to generate—already heavy traffic can be quickly complicated when, to accommodate an approaching interchange, four lanes suddenly open to six or six suddenly opens to eight. In quick succession, a series of overhead signs, all the same size and color with no distinguishing or helpful indicators, give at best loose direction for quickly approaching exit ramps designated most often by mileage markers and giving options for interchange actions listed, most often, by a series of destinations, roads, or adjacent towns.

These decoders of the fast-approaching highway interchange, however, slip quickly behind the driver. GPS systems help, of course, but even as the driver begins to navigate in the widened lanes and prepares to change sometimes multiple lanes and then to maneuver to a tightly spaced exit ramp and then into a complex of surface streets to join ongoing traffic, decisions have to be made in seconds. Hesitating in maneuvers can lead to weaving, perhaps the most challenging feature for highway ramp designers to combat. Unless the driver is familiar with the highway system, decisions about where to go and when are complicated by the potential for anxiety and confusion in what can quickly become a living maze. Maneuvering through interchanges requires maximum driver attention and focus. More than 20 years ago, highway engineers in cooperation with a variety of medical commissions gathered data on the human factor involved in engaging highway interchanges and ramps and found a number of telling signs to indicate driver panic: dry lips, accelerated heartbeat, the release of adrenaline, sweaty palms, and uneasy stomach. The science and engineering of highway exchanges must take into consideration not only traffic flow requirements, local politics, cost effectiveness, supporting infrastructure conditions, business and industrial development, and environmental topography, but also the mental and emotional variables in the hundreds of thousands of drivers who will navigate the system over its decades of use. These variables might also include problems such as driver distractions (food, cell phones, music, other riders), lack of driving experience, and/or advanced age.

Basic Types

The Federal Highway Administration in conjunction with individual state departments of transportation and transportation engineers, in

approaching the design or upgrade of any highway interchange, must balance the need for efficiency and speed with safety and ease of use even as, given the ever increasing volume of traffic in major metropolitan areas, these interchanges expand, growing ever more complex. Although there are more than a dozen model types for highway interchanges, considerably more if hybrid models that bring together elements of multiple standard designs are considered, there are three basic models that give engineers and surface transportation planners options, each labeled by their geometric shape if seen from above.

The diamond. Law prohibits intersections on freeways. So to direct traffic onto the freeway, the diamond interchange permits the access of freeway traffic to minor surface roads or vice versa without interrupting the freeway's traffic flow. The interchange of a freeway and a surface street typically involves four one-way ramps: two in each direction, one to allow deceleration for the exit, the other acceleration for the access. The diamond interchange is the most basic and hence cost-efficient interchange design and one of the most widely used in interchanges involving relatively light traffic. The original intention of the diamond interchange was to make unnecessary traffic lights, as even relatively light traffic would overload the traffic light's efficiency. The freeway is separated and elevated from the surface street. Freeway thru traffic moves across the interchange unimpeded typically on a flyover, or overpass. Drivers exiting the interchange from either direction would access an off-ramp that runs directly to the surface road, essentially serving as the on-ramp, making the diamond shape. Where the ramps meet the roads are usually traffic lights or, depending on traffic flow (when the diamond interchange is used in less clogged rural interchanges), stop signs. But traffic running back onto the freeway is left unrestricted and able to merge. The problem with the diamond design has been in the movements between lanes as traffic lines attempt to navigate the merges.

The cloverleaf. By far the most familiar interchange (and among the earliest conceptual, the first patent for the four-leaf clover design was drawn before World War I), a cloverleaf is most often a two-level system that connects a freeway and surface street

using eight ramps and four loop ramps that handle all left-hand turns, those tight clustered ramps giving the interchange the cloverleaf look. To go left, vehicles first cross over or under the road they want to access, then bear right onto a sharply curved ramp that loops at roughly 270 degrees to complete the merge onto the interchanging road from the right and then actually crossing the route just departed. Thus, in a classic cloverleaf interchange traffic need never stop. In essence, drivers turn left by turning right until they are heading in what was left. In addition, cloverleaves were relatively inexpensive to construct because they required only a single bridge to handle multiple directional traffic, but the cloverleaf system required a significant land investment to provide the appropriately banked curved access roads.

In addition, cloverleaves demand precision lane maneuvering (they are not designed for traffic signs or stoplights) and weaving is a constant pressure because there is most often a very limited driving distance (often less than a half mile) between the on ramp of one cloverleaf loop and the off ramp of the next. Thus vehicles exiting the highway are often forced to cut off vehicles that just merged onto the highway. Safe driving spaces become significantly problematic, and traffic necessarily slows to accommodate the maneuvering, and there are other problems. Given the necessarily banked exit ramp network, larger vehicles, particularly loaded trucks, are given to tipping over when they approach the exits if they come off the highway at excessive speeds. Given the merging system, traffic snarls are common. Thus cloverleaves belong generally to older transportation system designs and are for the most part now constructed only in relatively low-traffic flow areas, such as suburbs or in towns.

Many existing cloverleaves have been radically modified with elements of the diamond interchange, reconstructed with ramps connecting now to smaller roads that parallel the highway, called collector-distributor roads, that in turn help relieve traffic, ease the confusion, and minimize driver error as the parallel roads can be maintained at a much slower speed limit (often 40 or 45 miles per hour), which reduces the hazards of cloverleaf exiting when vehicles move at higher speeds.

The stack interchange. In the increasingly dense population centers, interchanges must network two



The five-level stack interchange, known as the High Five Interchange, was completed in 2005 in Dallas, Texas. Its design includes reversible high-occupancy vehicle lanes as well as 37 bridges. Its highest points are as tall as a 12-story building.

major highways, rather than a major highway and a lesser surface street. The stack accommodates that larger conceptual. The stack is a massive (and often intimidating) complex of two pairs of left-turning ramps stacked at an imposing height in a network configuration above, below, or even between the two interchanging highways. Because all left-handed turns are executed on flyovers or underpasses, the traffic choreography in a stack interchange can be quite busy, but because the traffic is moved to the left using flyover ramps and underpasses, there is no need to weave, eliminating one of the most persistent safety hazards in interchange design. A stack interchange can be far more expensive to construct, require more time for construction, and take up considerably more acreage than more conventional interchanges, but it can also be far safer.

The look of stack exchanges can become part of the aesthetics of a postmodern city. The first

completed stack interchange, opened in Los Angeles more than 60 years ago, featuring seven bridges and 22 lanes, has become one of the most photographed images of the city; the interchange's imposing criss-cross hatch of flyovers and ramps and its nearly-constant whirl of traffic in tightly patterned dedicated lanes has come to represent the raw energy of the city and has figured prominently as the backdrop for dozens of films and television shows, valued for its industrial aesthetic, its elegant simple lines and intricate maze-like feel. But the stack interchange is not universally admired—residents who have to deal with the visual impact of the monolithic interchange construction on a daily basis often wage significant public campaigns to prevent stack interchanges from even being built.

New Developments

Perhaps the most exciting development in interchange design in the 21st century is the diverging diamond, which addresses the problem with lane crossing in high-volume diamond interchanges that involve traffic trying to access major highways and thru traffic maintaining their lanes on minor streets. Rather than compel individual cars to maneuver across lanes, the design simply shifts the entire lane of traffic.

The divergent diamond provides a series of synchronized traffic signals that actually send motorists for a few seconds to the opposite side of the road in which they are heading before moving the entire lane back to the other side in a kind of criss-cross design, and there permitting entrance traffic to the highway or thru lanes. Vehicles no longer cross opposing traffic lanes, which (barring traffic accidents or unanticipated conditions) allows for unrestricted movement through the interchange (what designers call “green time”), easing congestion and making the interchange far safer to navigate.

The design, of course, can throw drivers as they must move even briefly away from where they want to drive—in fact states that have already installed these interchanges have provided extensive YouTube animation to help explain to drivers the concept and operation of the interchange. Because the interchange does not require extensive construction—it can use any bridge and ramp system already in place—and because, in turn, the

construction time is minimized, the diverging diamond is considered the critical key in new interchange design.

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See Also: Highway Design and Engineering; Highway Interchanges; Road Signage; Traffic Flow.

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Highway Interchanges

A highway interchange is a type of road junction that allows highway traffic to pass through the junction without intersecting with other traffic. This is usually accomplished with grade separation, the construction of transportation routes at different heights for the purposes of avoiding mutual disruption. In this sense highway interchanges are a descendent of grade-separated railroad junctions, which originated to prevent road traffic from intersecting with the rails. Interchanges are an alternative to the use of traditional intersections with traffic lights or four-way stop signs, because with the higher speed and more dense traffic of highways, stops are more likely to cause traffic jams, and accidents caused by those who run the stop or fail to brake in time are both more likely and more severe.

A complete interchange includes sufficient exit ramps (which lead traffic onto the intersecting or proximate road) and entrance ramps (which lead traffic onto the highway) to provide access both to and from all directions, which generally means

either four ramps (when intersecting with an ordinary road) or eight ramps (when intersecting with another highway). Interchanges can become complicated when multiple roads are involved, when highway exits and on-ramps are proximate, or when multiple grade separations are used within a short distance, all of which can create confusing traffic patterns, increase the amount of traffic that must change lanes, or increase the complexity faced by merging traffic.

There are a number of different highway interchange designs, some of which are meant for specific numbers of roads or other local conditions. One of the earliest developed was the diamond interchange, generally used for a highway crossing a more minor road. In such interchanges, the highway continues over the road via a bridge, while off-ramps diverge at a slight angle to meet the intersecting road and become an on-ramp back onto the highway on the other side.

This is one of the simplest forms of interchange and does not considerably add to the space needed for the roads, especially compared to more complicated interchange systems. It remains common throughout the rural United States and in many suburban areas. Moderate variations on the diamond design include the double roundabout, which combines the basic idea of the diamond interchange with the use of two roundabouts (one for each direction of traffic), which is used on several western interstates as well as in Minnesota; the tight diamond, a diamond interchange used in urban areas and other places with insufficient right-of-way; and the dogbone interchange, which uses modified roundabouts that don't form a complete circle.

Areas with heavy traffic may require other interchange types, with additional lanes for turning. In urban areas a directional interchange is often more common. A directional interchange, also known as a stack interchange or butterfly junction, uses two pairs of left-turning ramps. The design was first used in Los Angeles at the Bill Keene Memorial Interchange, which connects U.S. Route 101 to State Route 110, and opened in 1953.

The Bill Keene Memorial Interchange was designed because local terrain and neighboring buildings made it infeasible to construct a cloverleaf interchange, which was the default design of the time and still frequently in use. Cloverleaf



A cloverleaf interchange loops through landscaping near Cologne, Germany. The cloverleaf design was first popular in Europe and Latin America; the first U.S. version was built in 1929 in New Jersey. Some have since been converted to updated designs.

interchanges had been designed by civil engineer Arthur Hale in 1916, and though considered for earlier interchanges, the first to be built in the United States was the Woodbridge Interchange at routes 25 and 4 in Woodbridge Township, New Jersey, in 1929. Cloverleaf designs had in the intervening time been implemented in Europe and Latin America; in fact, the Woodbridge implementation was based on a plan used in Buenos Aires, Argentina. They are so named because from an aerial view or on a map, their design resembles the symmetry of a four-leaf clover. Each “leaf” is a ramp conducting traffic along a 270 degree turn in order to merge onto the intersecting road (turning left thus requires a right-hand turn onto this ramp).

Interchanges which use the cloverleaf design but have fewer than four ramps forming “leaves” are considered jughandle interchanges. Cloverleaf interchanges predated the development of the interstate highway system in the 1950s and were

accordingly the most popular interchange design during most of the time when that system was being built. Other than space considerations, which the aforementioned directional interchange addresses, their major drawbacks are the traffic complications—known as weaving—caused by exiting and entering traffic using the same lane, and the possibility of trucks (because of their different center of gravity and weight distribution) toppling when traveling the loops at illegally high speeds.

For those reasons and others, some original cloverleaf intersections have since been converted to other designs. An increasingly popular choice is the single-point urban interchange (SPUI), a modification of the diamond interchange, which was designed for heavy traffic flow. Unlike a normal diamond interchange, a SPUI allows opposing left turns to occur simultaneously, and a single set of traffic signals is sufficient to control traffic.

The first SPUI was built in Clearwater, Florida, in 1974, and became popular because of its space efficiency, though a conventional (and cheaper) diamond interchange without traffic signals is sometimes preferred. SPUIs require a very large expanse of pavement, and although there is an obvious advantage to allowing simultaneous left-hand turns, left-hand turns are also the most frequent source of collisions. This collision problem has been addressed by the development by engineer Vener Tabenero of upstream signalized crossovers, which relocate left-turn lanes and use traffic signals to control criss-crossing lanes, which avoid collisions.

SPUIs can also be difficult to keep clear of snow in the winter, though this has not prevented their widespread adoption in northern snow-prone states like Connecticut (which uses a SPUI at the junction of Connecticut Route 111 and the Merritt Parkway), Idaho, Indiana, Michigan, New Hampshire, and New York. Even Alaska uses several SPUIs, including two on the Johansen Expressway in Fairbanks.

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See Also: Highway Design and Engineering; Highway Interchange and Ramp Design; Interstate Highway System; Traffic Engineering; Upstream Signalized Crossovers.

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Highway Landscaping

Highways are a form of transportation infrastructure. As such, they are part of an integrated system that also includes electricity lines and lighting, drainage and runoff systems, and increasingly, automated incident detection systems. Landscaping of highways has an aesthetic component, which aims to minimize the impact on the environment through restricting the effect of noise and air pollution. It also has a safety component, as careful landscaping can reduce the threat of snowdrifts or flooding and can also help stimulate the minds of drivers, thereby reducing the dangers of driver fatigue.

Landscaping also has a role in tourist promotion, sustainable development, environmental protection, and wildlife conservation. Because highways are customarily administered by the public sector, transportation infrastructure provides a public good, and the system of highway landscaping will also incorporate the issues of contracting the tendering, monitoring, and evaluation of performance. Landscaping projects need to be planned for the future, and existing projects must be maintained and improved where necessary.

Aesthetic Issues

The aesthetic issues involved with highway landscaping should incorporate perspectives from both road users and those by whom the road passes. Road users include drivers and passengers. Drivers have an important task and should not be distracted too much—there have been reports that accidents have been caused by large roadside billboards bearing particularly striking images. Where landscaping has contributed to the production of a site of particular

beauty or interest, therefore, it can be better to use road signs to guide drivers to parking spaces where they can observe the scenery in a safe manner—this also represents a retail opportunity, of course. In areas of spectacular scenery, for example, in parts of Switzerland, it is possible to integrate tourism management with highway and traffic management by routing tourist vehicles to designated pathways where the experience can be maximized and the intrusion minimized. In environmentally sensitive areas, tourists can be funneled into mass transit systems that use equipment that reduces the negative impact on the environment.

It is also possible for the consideration of the aesthetic appeal of a highway to be used to improve the appearance of industrial or suburban areas through which the highway passes by an encouraging or incentivizing approach to environmental management. This can contribute to better quality of life for many people in the vicinity of the landscaping project and also to economic regeneration of depressed areas. When combined with the use of alternative energy, highways can even promote sustainable development.

From the perspectives of residents whom the road passes, the aesthetic component relates to hiding the sight and sound of the traffic, since these represent forms of pollution and can also have a negative impact on property values—this is important in that it will promote local resistance to the construction of highways. On the other hand, it is possible for property values to rise in some cases when the landscaping improves the quality of life and the proximity of the highway represents an important locational advantage.

The aesthetic component also merges with the safety issue when highways are built close to or pass through residential areas. Particularly in less developed nations, highways tend to be built at as low a cost as possible and this means there is little if any barrier between traffic and residents, which is clearly a suboptimal situation. During the early period of rapid economic development in South Korea, highways were needed to link places of production with ports providing export services and, to reduce cost, were built without any lighting.

Safety Issues

In terms of road users, landscaping can make a contribution to safety by hindering snow drifts or

flooding and selecting plants and trees for roadside decoration that will not shed slippery leaves on the road at certain times of the year. The exact nature of the risks to be addressed here depends on geographical and climatic factors, as well as to the societal response to them. In Scandinavia, for example, there is an annual threat, often over an extended period, from dangerous conditions caused by the low temperatures and precipitation. However, because this is an anticipated threat about which people have abundant information and the resources to cope, the people generally respond rationally and risks are reduced thereby.

Similarly, in countries with few resources available along the road, as in the case of a number of sub-Saharan African countries, drivers and their assistants have had to become adept at maintaining and repairing vehicles using only the most rudimentary of equipment. However, when conditions are less predictable risks are increased because people cannot respond in such a rational and well-prepared way. In addition, the ongoing crisis of austerity that followed the economic crash of 2008 has accentuated problems by reducing the funds available for infrastructure generally, as the various collapsing bridges in the United States during 2013 have helped indicate.

Wildlife Conservation

Highways offer both threats and opportunities to wildlife as well as to farmed animals. Roads pass through the countryside and may intersect farmland. When this happens, the relevant highway authority may be required to make some provision to allow livestock to cross safely as part of the normal agricultural practice. Depending on the size of the highway and the topology of the surrounding terrain, crossing may be tackled by an overhead bridge or by a tunnel under the road. In some cases, this involves the prevention of the spread of disease. More sophisticated systems may be required in the event of areas of environmental fragility or of special scientific interest. In many developed countries, laws exist and are enforced to ensure that road construction is prevented in areas that hold protected species. In some cases, the application of science can be used to find solutions by landscaping the areas involved so that the flora or fauna can be protected.

Highway landscaping has already improved conditions for some types of wildlife. The regular

movement of traffic confuses earthworms, for example, along the grassy verges and banks and they rise to the surface more often and are preyed upon by raptors that have discovered this new and abundant source of food. The reserved area along the side of the landscaped road can act as a form of nature reserve in which some species can flourish when other habitats have been compromised.

Green Landscaping Issues

As the world has begun to provide increasingly obvious evidence of the impact of global climate change, design and implementation of green technologies has become an ever more urgent issue. To a certain extent, highway landscaping can never be a truly green endeavor because it relies on highways, which not only encourage resource use but make the greater use of resources a profitable and desirable activity.

Nevertheless, it is possible to consider the more efficient use of resources within the landscaping process and, in particular, the choice of materials. Plants and trees absorb greenhouse gases at different rates—mangroves are particularly efficient in this regard—and careful selection and mixing with native plants can help maximize the amount of product that can be recycled or reused. Some products of the landscaping process may be economically valuable.

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See Also: Climate Change, Transportation Adaption to; Environmental Impacts; Highway Aesthetics; Highway Construction and Maintenance; Livable Streets; Scenic Roads and Parkways; Visual Pollution.

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Highway Planning

Highway and bridge projects implemented under programs administered by the U.S. Department of Transportation's Federal Highway Administration (FHWA) may be eligible for federal funding if the sponsoring transportation agency project or public works organization meets certain standards in compliance with federal law, including conducting an environmental review. The environmental review process includes activities necessary to demonstrate that all potential project-related impacts to the human, natural, and cultural environment have been identified and that the effects of those impacts, such as economic or community benefits, have been taken into consideration before a final decision on the project is made.

In addition, the public must have the opportunity to be included in the project decision-making process as mandated by the National Environmental Protection Act (NEPA) of 1969. Typically, public involvement occurs at the first stage of the highway development process, which is the planning stage. The planning stage is followed by subsequent stages of development/preliminary design, final design, right-of-way, construction, and ongoing operation and maintenance.

It is during the first stage of the highway development process that the project is defined at the state, regional, or local level, based on the scope of the perceived problem and the proposed development solution. The most common types of problems predicated a call for highway development fall under one or more of four broad categories. Structural problems relate to existing physical structure that needs major repair or replacement. Capacity problems involve existing or projected travel demands that exceed available capacity and require increased access to transportation for greater mobility.

Issues related to safety occur when a route experiences an excessive number of incidents and accidents that can be resolved only through physical transformation of the route. Access problems are associated with developmental pressures along a route that make it necessary to reexamine the quantity, location, and physical design of access points. Solutions to all of these types of problems can be put into one of four types of improvement projects: new construction; reconstruction; resurfacing, restoration rehabilitation; and maintenance.

It is essential that all parties involved in highway development agree during the planning stage that a real problem exists, what the specific problem is, and whether the jurisdictional parties are willing to fix it. For example, road access may be identified as a real problem, but the jurisdictional community may prefer not to alter the status quo for fear of associated detrimental effects like increased traffic congestion.

The Government's Role

State transportation departments are required to develop and maintain a statewide, multimodal transportation planning process. The categories of highway improvement needs are defined in alignment with ongoing analyses of roadway pavement conditions and estimates of projected future traffic demands. Each state also is required to conduct inspections of its major bridges every two years and of its minor structures less frequently to determine their structural adequacy and capacity.

A number of states prepare regional transportation plans for multiple counties within the context of the statewide planning process. Every few years, the state selects improvement projects based on the long-range plan and includes them in the Statewide Transportation Improvement Program (STIP).

State efforts are supplemented in urbanized areas through the metropolitan transportation planning process. Metropolitan planning organizations (MPOs) develop their own regional plans, whereas most other areas are subject to the state planning process. The metropolitan planning process involves developing a long-range plan that defines the region's multimodal transportation needs and identifies local funding sources that will be needed to implement the underlying projects. The MPO then prepares a more detailed plan that prioritizes projects for work in the short term. The resulting near-term plan becomes part of a Transportation Improvement Program that is incorporated into the STIP.

Most of the smaller U.S. cities and counties follow a similar process of project determination, cost estimation, and prioritization regarding development projects for the roadways for which they hold primary responsibility rather than the state. The state's Department of Transportation will solicit local input for the STIP but typically does not become involved in the local development project itself.

Factors to Consider During Planning

For any highway development project it is essential that consideration be given during the predesign planning phase to the potential impact that a proposed modification or enhancement might have on the character, capacity, and culture of the surrounding area. FHWA projects must adhere to federal guidelines designed to ensure that planners evaluate possible adverse, economic, social, and environmental effects of proposed highway projects and locations.

The guidelines also stipulate that final project decisions must be made in the best overall public interest, which involves considering factors like the costs of eliminating or minimizing adverse effects of air, water, and noise pollution; destruction or disruption of natural and human-made resources; visual appeal, community unity, and availability of public facilities and services; adverse employment ramifications and tax and property value losses; and detrimental displacement of people, businesses, and farms.

Land use is also a key factor to consider during the highway development planning phase. Land use determines the function of an area's roads. Since land use tends to change periodically in response to growth and development, road function must be adapted accordingly. It is increasingly more common for rural farm access routes to evolve into roadways that service suburban residential subdivisions and commercial businesses. By considering land use during the project planning stage, design standards created in subsequent phases of development can better meet actual and expected changes in traffic character and road function over time.

Planning and Environment Linkages

The FHWA has established a planning and environment linkages (PEL) approach to transportation decision making. The collaborative effort involves considering environmental, community, and economic goals early in the transportation planning process and using the resulting information, analysis, and products developed to enlighten the environmental review process.

The PEL approach provides significant benefits for state and local transportation agencies. It helps build relationships and facilitates interagency integration, enabling all agencies to be more involved at the planning stage and more effective throughout

the decision-defining process for transportation projects. The enhancements to interagency relationships also may help agencies more quickly and easily resolve differences on key issues that might arise as the project moves forward through implementation.

Another benefit of the PEL strategy is improved process efficiencies and potentially faster delivery timelines. By reducing possible duplication of planning and NEPA processes, the PEL approach enables a singular cohesive flow of information among all parties involved. When transportation agencies conduct planning activities armed with information about resource considerations and in coordination with resource agencies and the public, they are more capable of designing transportation programs and projects that best serve the community's transportation needs. As such, the PEL approach ensures that transportation agencies have appropriate tools and information during the highway development planning stage to design better projects and minimize impact to the surrounding human, natural, and cultural environment.

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See Also: Benefit–Cost Analysis of Transportation; Environmental Impacts; Federal Aid Highway Program; Federal Highway Administration; Highways, Rural and Low-Volume; Interstate Highway System; National Environmental Policy Act; Public Participation in Transportation Planning; State Transportation Planning; Transportation Impacts on Land Use.

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Highway Removal

For most of the 20th century, highway removal was scarcely imaginable. Automotive traffic was growing, and road space was perpetually in short supply. Transportation policy was nearly synonymous with road construction. Only late in the century did a shift in priorities make the removal of roads conceivable, and occasionally even possible. Highway removal is a product of changing beliefs about the value and uses of inner-city land and about the role of automotive traffic in cities.

Changing Priorities

Although some roads slated for removal were considered underused, the growing interest in highway removal reflects changing priorities far more than declining car use. Most of these roads are in urban areas where planners, activists, or developers have foreseen more valuable uses of the land consumed by the highways. The roads were also blamed for dividing communities and for blighting adjacent neighborhoods with emissions, noise, and dangerous traffic. In addition, proposals to remove a road typically reflected a growing belief that cities need to move away from car-centric policies in favor of alternative models of both transport and land use. Proponents of highway removal wish to rebuild city centers on a pedestrian scale and promote investments in mass transit and pedestrian and bicycle infrastructure. They have typically emphasized the value of reconnecting urban spaces—cities to waterfronts, businesses to residential areas, and roads to adjoining buildings.

Typical candidates for highway removal are elevated urban express roads built around the middle of the 20th century to open up congested city centers to free-flowing auto traffic. When these aging roads need major structural repair, it becomes more plausible to argue for the cost-effectiveness of removing or replacing them. Most are in the United States, since far fewer inner-city freeways have been built in other lands. Proposals to remove them have been initiated in part by city officials and in part by citizen initiatives.

An unusually early example is the removal of Harbor Drive in Portland, Oregon, in 1974, and its replacement by a riverfront park. This expressway into the city center, opened in 1943, was a typical mid-century urban highway, although it was

connected to other freeways at only one end, and had been made partly redundant by two newer freeways. Even then, its removal can be attributed to unusual civic leadership. Another unique case was New York's elevated West Side Highway, which had to be closed in 1973 because of structural deterioration and which was eventually replaced by a boulevard—a decision that came only after controversial plans for an upgraded freeway were cancelled in 1985.

The decision to remove a road came more easily where it had never been completed in its full length or had been intended to connect to another road that was never built. (An extreme case is Baltimore's "Highway to Nowhere," which was never connected to planned freeways at either end, and which was partly demolished after 2010.) Among the best-known examples are two from San Francisco. The Embarcadero and Central freeways were both elevated inner-city stumps, never completed, and damaged in a 1989 earthquake, after which the city decided to tear them down and replace them with multiuse boulevards. Other examples of removed freeway stumps from the early 2000s include Milwaukee's elevated Park East freeway, one end of Toronto's lakefront Gardner Expressway, and the Oak Street Connector in New Haven, Connecticut. The Chattanooga (Tennessee) Riverfront Parkway is a case of an underused highway that was downgraded to a narrower, slower street. A similar example is the Robert Moses Parkway in Niagara Falls, New York.

Among the few examples outside the United States is the Cheonggye Expressway in Seoul, South Korea, which had been built through the city center atop the buried Cheonggyecheon River. It was removed in 2003 and replaced with a restored stream, linear park, and streets. In Paris, France, the Seine riverbank expressway from the 1960s has recently been closed in the city center. Both Seoul and Paris closed these roads as part of a comprehensive strategy to reduce inner-city automotive traffic, including transit improvements as well as restrictions on car traffic.

Road Capacity

In nearly all the cases of highway removal, fears of traffic gridlock did not come to pass. Any proposal to remove a highway is certain to attract vehement opposition from those who argue that the result will

be traffic congestion on parallel roads or replacement streets. Such fears are often exaggerated, however, as former freeway users find alternate routes, choose alternate modes, accept slower speeds, or simply drive less. Although critics are correct to note that slower, narrower roads cannot carry as many vehicles per hour as the freeways, they sometimes fail to question their assumption that driving patterns will remain unchanged even when roads do not.

However, some plans to remove hated roads have depended on the replacement of all the lost road capacity. In these cases an ideal solution is a tunnel that frees up land and removes cars without reducing road capacity. The most notable example is Boston's "Big Dig" that buried its elevated Central Artery. That project in the 1990s and 2000s became so notoriously costly (at least \$14 billion) as to discredit this approach. Nevertheless, in 2011 Seattle voters approved a tunnel to replace the elevated Alaskan Way viaduct along the city's waterfront. "Highway relocation" might be a better label than highway removal for these tunnels, as well as for inner-city freeways that have been rerouted away from the city center, as in Oklahoma City and in Providence, Rhode Island.

Effects

Where freeways have been entirely dismantled, they have typically been replaced with boulevards, which trade slower speeds and reduced vehicle capacity for multimodal use, pedestrian access, and direct connections to side streets, sidewalks, and adjacent buildings. Instead of a limited-access motor road, the result is a street—a road integrated into the city, lined with buildings, consuming less space, and freeing up some land for other uses, including new buildings and parks. In most cases, the replacement of demolished freeways has been governed by the principles of "complete" or "livable" streets—the polar opposite of the typical freeway.

Local initiatives are urging the removal of freeways in many more cities, including Toronto; Syracuse, Rochester, Buffalo, and the Bronx, New York; New Orleans; Louisville, Kentucky; Nashville, Tennessee; Washington, D.C.; Trenton, New Jersey; Cleveland, Ohio; Baltimore, Maryland; Hartford, Connecticut; and St. Louis, Missouri.

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See Also: Complete Streets; Highway Construction and Maintenance; Livable Streets; Road Diets.

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Highway Safety Barriers and Traffic Barriers

Each year, more than 6,840,000 people in the United States are in roadway accidents. Annually, accidents injure 3,511,000 people and kill 41,907. Highways are dangerous, and until the middle of the 20th century, the assumption was that the death toll was inescapable because these deaths were caused by driver error. Only in the 1960s was an effort begun to make highways safer by reducing or eliminating hazards on roadsides or by placing barriers between hazards and errant vehicles.

The barriers are not foolproof nor a total solution, as fatalities remain high. As of a 2003 report, 38 percent of fatal crashes nationally involved single vehicles leaving the road and either hitting a fixed object or overturning. The United States recorded 821 fatal head-on crashes due to median crossovers on the interstate system in 2006.

Traffic barriers such as guardrails and safe highway drainage designs keep the numbers from being even higher. To ensure uniformity across jurisdictions, the federal and state governments publish standards for placement and design of signs, posts, and other barrier technologies. The federal *Manual on Uniform Traffic Control Devices* (MUTCD) specifies minimum offset distances for signs, and mandates breakaway, yielding, or barrier-shielded

signposts in clear zones. A clear zone is an area near the driving surface that is free of hazards. Clear zones can vary—from as narrow as less than 10 feet to as wide as 30 feet, depending on speed, traffic volume, roadway geometrics and classification, and slope. Even low-volume roads have to conform to the clear zone standards. A clear zone is a flat and unobstructed area off the edge of the road where errant vehicles can recover. Width depends on traffic volume, intended speed on the road, and embankment slope.

Similar standards apply to temporary signs in work zones. For rural roads with only local traffic the standard may be waived because the assumption is that the users are familiar with the road hazards and adjust accordingly. Iowa began in 1989 flattening driveway slopes on farm to market roads, approximately 15,000 of them by 2003. Iowa also developed a public information campaign in 2002 and developed a detailed inventory of all county roadsides, as well as a mitigation plan for obstructions identified in the inventory, including removal, relocation, and remodeling to incorporate breakaway and barrier features.

Purposes

A forgiving roadside allows a driver to err, gives that driver time and space to correct the mistake, and eliminates as many as possible hazards to the errant driver. Among the hazards are bridges, trees, mailboxes, poles, guardrails, embankments, and ditches. Anything that interferes with the safe halting of the vehicle or its return to the roadway under control is a hazard.

Barriers are routinely employed to block collisions with roadside signs, but this is not necessary in all cases. Small signs or signs with breakaway posts are less of a danger than a barrier would be. Obstacles outside the clear zone also do not require barriers (the clear zone or horizontal clearance or clear recovery area is the lateral distance on a recoverable slope that a vehicle can travel off the roadway and still return to the roadway safely; it is contingent on speed limit and type of roadway) as long as there are no steep slopes or fixed obstacles in the clear zone.

The purposes of a barrier are to keep vehicles from departing the roadway and from colliding with walls, buildings, drains and culverts, and other dangerous obstacles. Placed beside the road, they block

vehicles from climbing steep slopes or driving into deep water. On medians of divided highways they block vehicles from entering the opposing lanes, thereby reducing the risk of head-on collision. A barrier serves to limit the severity of an accident (as when a vehicle or vehicles leave the roadway) only when hitting the barrier is a lesser harm than leaving the roadway. Considerations for designing the appropriate barrier include traffic volume, speed, distance to the hazard from the roadway, and distance to the barrier from the roadway. Types of barriers include longitudinal barriers such as guardrails and median barriers and crash cushions.

Bridge barriers are higher than roadside barriers because they have to prevent buses, pedestrians, cyclists, and trucks from rolling or vaulting over the barrier and off a bridge onto a railway, roadway, or river. Multirail tubular steel barriers or reinforced concrete barriers and parapets are used for this purpose.

Median Barriers

Because modern highways are commonly divided by medians that can be crossed by an errant vehicle in split seconds, there is a need to reduce the likelihood of said errant vehicle moving across the median and into oncoming traffic. Also, in construction zones with traffic flowing in both directions at high speed in close proximity, median barriers help reduce head on collisions. Barriers made to withstand contact from either side are called median barriers. Median barriers are designed to prevent head-on crashes from a vehicle leaving its lane and crossing into oncoming traffic. Roadside barriers protect from one side, but median barriers must withstand contact from either side.

Median barriers, the longitudinal barriers that separate opposing directions of traffic on a divided highway, do not reduce the frequency of roadway-departure crashes, but they do help keep a median crash from being a head-on collision. At highway speeds a vehicle can cross the median and collide head-on in the length of a yawn. Barriers must be designed and placed properly if they are to protect oncoming traffic and the occupants of the straying vehicle at the same time.

Barriers can also come in a variety of configurations and materials. Selection criteria include types of vehicles using the highway, configuration of the roadway, and the potential severity of a head-on

due to median crossover. For most circumstances, standard barriers that can redirect cars, vans, and trucks will serve. Longitudinal barriers are primarily intended to redirect vehicles and keep them on the roadway.

However, high traffic volumes and speed or a large number of heavy trucks on a roadway of unusual configuration or in a difficult environment can demand more stringent measures. Rigid barriers are commonly made of concrete. Initial installation is expensive, but concrete offers relatively low cost over the life cycle, virtually no maintenance, and a good safety result. Because they absorb the least energy of the three categories of barrier, concrete barriers may produce more severe injuries, but overall, they are a highly effective mitigation device in high-volume and high speed roadways. They also work well in high truck traffic environments. Concrete barriers are also appropriate when median width precludes installation of other barrier types.

A concrete barrier has little or no flexibility, redirects vehicles back to the shoulder or their lane, and works best where two-way traffic occurs in close quarters and there is no room for a median. However, a concrete barrier is not necessarily best in all situations. If there is a realistic opportunity that a driver can get off the road onto a level median and recover, then that is preferable to colliding with an inflexible concrete wall. If the median or shoulder is not large enough, then concrete is the better choice. Criteria for location and type of barrier include accident history, prevailing speed, volume of traffic, curves (road geometry), cost of installation and maintenance, grade and slope, and amount of shoulder and median space. Environmental concerns and the characteristic of the given type of barrier are also factors.

The semirigid barrier is more commonly known as a guardrail or guiderail. It involves segments of metal railing held together by posts and blocks. It works well in traversable medians with minimal cross slope or grade change. These barriers are cheaper than rigid barriers but are more difficult to install in poor slope or difficult grades. They also have to be repaired or replaced after a collision, so life cycle cost may be higher. Guiderail systems absorb energy during crashes and move or deflect on impact.

Cable barriers consist of several steel cables connected by posts. They minimize impact forces on

the vehicle and occupants and absorb most of the kinetic energy. They are usually the cheapest to install, but they require maintenance after a crash. Still, they are the most forgiving and versatile of the barrier types.

One type of high-tension cable system design reduces deflection and resists impact forces. This type of system is easier to repair if a post is damaged and is also more practical in narrower spaces. Cable median barriers allow a vehicle to stop without reentering traffic, provides for water to flow underneath, works well with wide medians, and flexes up to 12 feet.

Regardless of the type of barrier chosen, ease of maintenance is extremely important. A single crash may damage several posts or sections of a barrier. Until repair is completed, the barrier is inadequate for protection against any crossovers.

Roadside Barriers/Guardrails

Danger comes at the side of the road as well as in the median. Traffic barriers are routinely placed near steep slopes close to roadway edges, at bridge

ends, at culverts or drainage crossings with vertical or steep drops, and near light poles or large signs or other roadside fixtures that may constitute hazards. Roadside barriers protect traffic from such hazards as steep slopes that might cause a rollover, fixed objects such as bridge piers, and bodies of water.

Initially, barriers had no special modification at their ends so vehicles colliding with a blunt end could either stop sharply or have a steel rail enter the passenger compartment. Often the result was severe injury or death. To correct the problem, barriers were modified with the addition of an end that brought the barrier to the ground. This style ended the problem of penetrations but, because it formed a ramp at barrier's end, led to occasional instances of vehicles vaulting into the air or rolling over.

The next iteration was incorporating energy absorbing terminals, including a large impact head to receive the bumper or vehicle frame, which drives the impact head back along the guiderail, allowing contact energy to dissipate as the steel rail bends or tears. Another approach is to curve the guiderail back sufficiently that the terminal is not susceptible to head-on contact, preferably because it is embedded in a cut slope or hillside.

Rail end treatments provide effective deflection and absorption of oncoming traffic without spear-ing. Rail end treatments are available in a wide variety of end types, including flares, question marks, 90-degree turns, and several identified by federal standard number or letter (ET2000, ET-Plus, XRT-350, SKT-350, and Regent-C.) Further strengthening the absorbent capability of guardrails are blockouts, spacer blocks that separate the rail from the post; spacers are no longer steel because plastic and wood are safer.

The National Crash Analysis Center (NCAC) has made great strides in determining the safest guardrail posts for highway use. The NCAC developed computerized crash simulation finite element (FE) models, which were used in combination with traditional crash testing to determine the optimal post for highway use.

Finite elements recreated the explicit geometry, weight, inertia, and mass of each guardrail component. Comparisons to full-scale crash tests have validated the accuracy of finite element models. These tests helped determine the optimal choice of blockouts, steel gauge, and post gaps for optimal guardrail performance.



The rounded end of a guardrail in Burtonsville, Maryland, in 2007 is painted with a reflective coating. The coating used was a bright yellow to make it more visible at night.

Barriers are defined as flexible, semirigid, or rigid, based on amount of deflection when struck by a vehicle and what means the barrier uses to resist the impact. The American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* is the current U.S. standard, replacing the Federal Highway Administration NCHRP Report 350. Flexible barriers, including cable and weak-post corrugated guiderail systems, dissipate energy through tension in the rail elements; deformation of the rails, posts, and vehicle body; and friction between rail and vehicle.

Semirigid barriers are the box beam guiderail, three-beam guide rail, and heavy post blocked-out corrugated guiderail. They are sturdier than flexible rails and dissipate impact energy similarly but can spread impact over a greater number of posts because of the rigidity of the tube.

Rigid barriers are usually made of reinforced concrete formed into a shape that guides the vehicle along the length of the barrier rather than allowing the vehicle to collide directly with the barrier. The vehicle crumples as it slides along the barrier, dissipating collision energy.

F-shape and Jersey (originally a type developed by the New Jersey highway department but now a generic term) concrete barriers are also shaped so that tires will ride up the lower section, causing the vehicle to lift and slow. Low-angle or low-speed impact may produce only minimal vehicular damage, but for small cars there is a significant increase in risk of rollover.

Other barrier types are constant slope and concrete step, and barriers can be either smooth concrete or have faux stone or stone finishes for esthetic reasons (these barriers have vertical faces so cars cannot climb them.)

Guardrails flex up to 3 feet, allow water to pass underneath, give drivers some control after impact, and work in areas with steep slopes. Galvanized guardrails can be either 12-gauge (class A) or 10-gauge (class B) steel, most commonly in the form of the W-beam, rails roll-formed into a W-shape to catch a car bumper. This type of rail creates a long barrier whose purpose is to minimize damage from a run-off-road collision by absorbing and dispersing impact over distance. W-beam guardrails are economical and effective.

Guardrail posts on state and federal highways have to conform to a higher standard based on an

NCHRP 350 report. State and federal highway post regulations have recently been updated after an NCHRP 350 report determined that wooden posts provide increased safety over steel posts. Guardrail post safety is a concern of the National Crash Analysis Center (NCAC), which uses computerized simulations and traditional crash testing to determine which post is best. The NCAC tests also determine the best steel gauge, post gaps, and blockouts.

Prevention of Flooding

Heavy rains can cause flooding that impedes or endangers traffic. When possible, culverts route water from the roadway surface either through the embankment or by means of a channel. Culverts have to be strong enough to handle road traffic and an overburden of earth. Culverts must offer minimal risk of damage to property or traffic due to failure. Drains empty the roadway of water so that traffic will not be hampered. Drains serve where culverts are impractical, usually in heavily built urban areas. Drains can incorporate cuts into the curb, grates, slots, or a combination of the three.

Temporary Barriers

Barriers are essential in permanent configurations such as the divided highway or the traffic lane with an insufficient clear zone due to natural obstacles along the roadside. Additional purposes for safety barriers come with more temporary situations. Temporary barriers are different in style and purpose from permanent ones. Traffic barriers to route vehicles and pedestrians clear of danger come in many forms, and they are useful for blocking access, controlling crowds, diverting traffic, and completely closing roads. They range in size from cone to temporary wall, and when filled with water are quite strong and stable. Other options include modular and plastic expanding barricades. Other names for traffic barriers are crash barriers and Armco barriers (a genericized trademark of AK Steel, formerly Armco.)

Crash barriers serve not only to restrict errant vehicles but also to protect vulnerable areas from said vehicles. Crash barriers protect pedestrian zones, fuel tanks, school yards, and the like.

For work zone hazard protection, movable barriers are preferred. Temporary concrete barriers are one type. Another is the water filled barrier, steel reinforced plastic boxes that can be linked together longitudinally. When filled with water they provide

a substantial wall. They are convenient because they do not require heavy lifting equipment for placement, but they are not suitable for freezing weather.

Impact attenuators reduce risks due to wider hazards that are not amenable to protection by the single-sided traffic barrier. Also known as cowboy cushions, crash cushions, or crash attenuators, impact attenuators absorb kinetic energy and redirect vehicles away from hazards or road construction equipment and crews. They are located in front of fixed objects such as gore points, Jersey barrier introductions, or overpass supports. Temporary types are common on road construction.

Snow plows and other road equipment incorporate truck-mounted impact attenuators. Attenuator trucks have to maintain a specified distance from workers or machinery, particularly in mobile work zones. Rows of sand or water-filled barrels are one type of attenuator that works by momentum transfer as the sand or water absorbs the speed of the colliding vehicle. Newer attenuators of the material deformation style use crushable material to form a crumple zone to absorb energy. Material deformation style also includes corrugated steel guard rail that flattens on impact or a steel box beam that splits to absorb the blow. Some attenuators force a steel cable or strap through a slot or tube to convert kinetic energy into heat.

The widely used Fitch Barrier is a sand- or water-filled plastic barrel, commonly yellow with a black lid. In a triangular configuration at the end of a guard rail between a highway and exit lane (the gore), these barrels are arranged so each successive one has more sand. Vehicle contact shatters the barrels, and the scattering sand dissipates the energy, causing a smooth deceleration rather than a violent collision. Since they were developed by race car driver John Fitch in the 1960s, they have saved up to 17,000 lives.

Conclusion

Barriers are designed to minimize injury to vehicle occupants but, being mostly immovable objects, they do sometimes cause injury. Therefore, they should be used only when the alternative damage from contact with the obstacle the barrier blocks is probably worse. Rather than adding a barrier to an obstacle, the better course if feasible is to remove or alter the obstacle. Traffic barriers undergo simulated and actual crash testing to guarantee effectiveness

and safety, but no test can cover every scenario. They can, however, minimize probability of damage by ensuring that the barriers perform at a satisfactory level to protect vehicles and passengers and other users of the roadways.

Barriers alone do not guarantee safety. Additional measures include rumble strips to wake drivers straying out of the lane, speed enforcement, and speed limits. And the driver has an obligation to be alert, maintain the vehicle, adjust for weather and traffic, and not drive under influence of drugs or alcohol.

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See Also: American Association of State Highway and Transportation Officials; Automobile Accidents and Prevention; Highway and Road Safety; Highway Design and Engineering.

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Highway Trust Fund

The Highway Trust Fund (HTF) was established by the Highway Revenue Act of 1956 as a mechanism to finance an accelerated highway program (including construction of the Interstate Highway System) by ensuring a dependable source of financing for the Federal Aid Highway Program (FAHP). Though federal motor fuel and motor vehicle taxes existed before the creation of the HTF, their receipts were deposited into the U.S. government’s General Fund and had no specific relationship to federal funding for highways.

The Highway Revenue Act directed the deposit of revenues from certain highway-user taxes into the newly created HTF for use in financing programs enacted in the Federal Aid Highway Act of 1956. Taxes dedicated to the HTF have continuously been extended by Congress and the HTF has become the primary source of federal funds for the FAHP.

History and Key Legislation

Before 1956, funding for the FAHP came from the General Fund of the Treasury. Highway-user taxes, such as those on motor fuels and automobile products, existed but were not linked to highway funding. However, the Federal Aid Highway Act of 1956 significantly expanded the FAHP, which required more extensive and consistent funding if the states were to adequately plan for the longer term. To make the FAHP self-financing and to provide longer term continuous funding, the Highway Revenue Act of 1956 established the HTF and dedicated 100 percent of federal motor fuel tax receipts and a certain percentage of receipts from highway-user taxes (such as on tread rubber, tires and inner tubes, trucks, buses, etc.). Furthermore, this legislation authorized an increase in the federal gasoline tax from 2 to 3 cents per gallon (cpg).

Originally created as a temporary trust fund to provide funding for interstate constructions, the HTF and the taxes dedicated to it have been continuously reauthorized and extended. However, while the basic principle of HTF as a fund with dedicated revenues from taxes paid by highway users has remained in effect, the tax rates and allocations of tax revenues that originally underpinned the HTF have changed over time.

Major revisions occurred as a result of the Surface Transportation Assistance Act of 1982 and the Deficit Reduction Act of 1984, which increased fuel tax rates and established a Mass Transit Account in the HTF to receive a portion of the fuel tax revenues. Another increase of 5 cpg was enacted as part of the Omnibus Budget Reconciliation Act of 1990 (OBRA 90), which also fundamentally changed the revenue structure underpinning the HTF. Whereas previously all revenues from the federal motor fuel tax went into the HTF, only half of the revenues from the 5-cent increase would now go into the HTF and the other half would go to the General Fund of the Treasury for deficit reduction.

The General Fund portion of the tax was imposed on a temporary basis and scheduled to expire on October 1, 1995. The Omnibus Budget Reconciliation Act of 1993 extended the temporary General Fund tax increase of OBRA 90 but directed the revenues toward the HTF. This legislation also increased the tax by 4.3 cpg, bringing the gasoline tax to 18.4 cpg, with the incremental revenues going to the General Fund for deficit reduction.

The Taxpayer Relief Act of 1997 subsequently redirected the 4.3-cent General Fund tax to the HTF effective October 1, 1997. This was the last change to the federal gasoline tax rate. The motor fuel tax underpinning the HTF was most recently extended through September 30, 2016, by the Moving Ahead for Progress in the 21st Century Act (MAP-21).

Structure and Revenue Sources

The HTF is a financing mechanism established by law to account for federal tax receipts dedicated or earmarked for specific types of transportation expenditures. Originally, the HTF focused solely on highways, but this changed when the Mass Transit Account was created within the HTF and a portion of HTF revenues set aside in the account. Although

never legally described and named, the portion of the HTF outside the Mass Transit Account has been called the Highway Account and it receives all HTF receipts not specifically designated for the Mass Transit Account. In 2011, the gasoline tax was 18.4 cpg and the diesel tax was 24.4 cpg. Of both taxes, 2.86 cpg went into the Mass Transit Account and 0.1 cpg went into the Leaking Underground Storage Tank Trust Fund. The remainder was deposited into the Highway Account.

Tax revenues directed to the HTF are derived from excise taxes on motor fuel and truck-related taxes (specifically on truck tires, sales of trucks and trailers, and heavy vehicle use). In fiscal year 2011, total receipts for the HTF totaled \$36.9 billion, and expenditures were \$44.5 billion. Gasoline taxes composed 64 percent of total receipts for the HTF, and taxes on diesel and special motor fuels composed 25 percent. Truck-related taxes contributed 8 percent of revenues, with a large portion of this revenue generated by the tax on sales of trucks and trailers.

In terms of the distribution of expenditures, 81 percent of HTF expenditures were for programming by the Federal Highway Administration, 16 percent (mostly from the Mass Transit Account) were by the Federal Transit Administration, and the remaining expenditures were by the Federal Motor Carrier Safety Administration and National Highway Traffic Safety Administration.

All revenues from the three truck-related taxes go into the Highway Account of the HTF. The first is the truck tire excise tax, which is imposed on truck tires with a maximum load capacity over 3,500 pounds. This tax is based on the maximum load capacity at the rate of 9.45 cents for every 10 pounds over 3,500 pounds. The truck and trailer sales tax applies to the retailer's sales price of tractors and trucks over 33,000 pounds gross vehicle weight (GVW) and trailers over 26,000 pounds GVW.

The tax of 12 percent also applies to parts and accessories sold in connection with the vehicle sale. The heavy vehicle use tax is an annual tax on the ownership of trucks that weigh over 55,000 pounds GVW. For trucks between 55,000 and 75,000 pounds GVW, the tax amount is \$100 plus \$22 for every 1,000 pounds (or fraction thereof) over 55,000 pounds. For trucks over 75,000 pounds GVW, the tax is \$550.

Distributions and Funding Challenges

Each state's highway users contribute to the HTF by paying motor fuel taxes and other highway-related user taxes. These funds are subsequently allocated from the HTF to the states according to a mathematical formula that attempts to relate resources to needs. A return ratio can be calculated that compares the funds paid into the HTF through revenues collected by motorists in each state with the state's total apportionments and allocations from the HTF.

A ratio of 1.00 indicates that a state receives the same amount of apportionments and allocations from the HTF as it contributes into the HTF. A ratio of less than 1.00 indicates that the state receives less from the HTF than its highway users contribute in motor fuel taxes (a donor state), while a ratio greater than 1.00 indicates that the state receives more than it contributes (a donee state). Donor states are located mostly in the southern and Great Lakes regions, while donee states are clustered mostly in the New England and mid-Atlantic regions.

One of the challenges to the HTF is that states, on average, receive more federal-aid funds than they put into the HTF. Since 1956, the return ratio for all states was 1.15; states received 1.15 times more funds than they contributed to the HTF. In addition to the problem of dispensing more funds than are paid into the HTF, the balance in the HTF has continually been a point of controversy. Given the nature of the FAHP as a reimbursable program, there is always excess cash in the HTF that is not needed for immediate use but that will be needed to reimburse the states as they submit vouchers for authorized work in the FAHP.

However, spending from the HTF has exceeded its revenues, and since 2008 the HTF has received almost \$35 billion in transfers from the General Fund. These transfers were \$8 billion in 2008, \$7 billion in 2009, and \$13.6 billion in 2010. The HTF also received \$6.2 billion from the General Fund in November 2012.

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See Also: Federal Aid Highway Program; Federal Highway Administration; Fiscal Politics; Highway Finance; Interstate Highway System; Motor Fuel Taxes; Moving Ahead for Progress in the 21st Century

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Highway Tunnels

Although it took engineers hundreds of years, tunnels came of age in the 19th century. Tunnels are, essentially, horizontal hollowed passageways that are cut through soil or stone. Tunnels provide solutions to traditional modes of transportation, whether it is necessary to traverse a physical barrier such as a mountain or create a solution to a modern problem such as too much traffic congestion. Tunnels fall under the jurisdiction of the Federal Highway Administration (FHWA) of the U.S. Department of Transportation (USDOT). Through advances in technology, the utilization of underground space has expanded tremendously within the last decade.

When building tunnels, planners must also take into consideration many safety concerns regarding workers, the materials through which they are

passing, and the unique geological conditions in which they're building.

Planning and Building

Although planning for and building different types of tunnels varies dramatically, there are some universal steps that can be applied to each project. Tunnel experts of the FHWA report that major aspects for consideration are: determining the alignment, clearances, and size of the bore; conducting a geotechnical investigation to determine the types of materials that the tunnel will be passing through; determining the probable construction method; investigating drainage and lining requirements; organizing safety provisions such as lighting, ventilation, communication signals, and power supplies; and establishing operation and maintenance procedures.

When there is a body of water a type of transport must cross, many factors are considered when determining whether a tunnel or a bridge should be built to provide a transportation solution. While tunnels are more costly than bridges, factors such as navigation for ships, land footprint, and congestion may make tunnels more practical solutions. With tunnels, developers can also avoid tides, weather, and shipping during construction and not be restricted in weight capacities.

Tunnels are the most expensive form of transportation construction and rely heavily on government funds. In addition to managing the overall project, civil engineers must consider the economic factors and politics that go into the decision to build a tunnel. The project duration, number of workers, materials needed, and the amount and type of land that must be excavated must be decided upon in the early planning stages. To swiftly bypass any political pushback, there must be an apparent need for a tunnel. In some cases, increasing taxes may be necessary to raise funds for certain projects and this often results in pushback from the community it impacts.

Geographical factors play a large role in determining the length of a project. Such factors, called "stand-up time," refer to the semisoft earth materials around the tunnel and how long they can safely stand on their own during the dig. Clay, silt, sand, gravel, and mud all have different stand-up times and they are influenced by factors around them, such as groundwater and fault lines. Stand-up time for hard rock is significantly longer, often by years, than soft materials, but, if stand-up times are not



A tunnel under construction in Sweden shows one of two planned concrete layers partially applied on top of a plastic lining intended to prevent water from entering the tunnel.

carefully considered, there is a risk of the ground caving in.

When creating a tunnel through hard rock, workers typically blast the rock or perform a technique known as fire-setting, in which the ground is heated with fire and then immediately cooled with water. Tunnel-boring machines (TBMs) are used to create tunnels in soft materials. This equipment is expensive, ranging into several millions of dollars, but it also provides support to surrounding rock. Other tunnels use a construction method referred to as the cut-and-cover method, which requires placing a tube in a trench and covering it with materials to keep it stationary. The tunnel is then covered with filler materials and excess water is pumped out.

Preservation

The long planning and excavation processes that go into tunnel building are only the beginning of the planning journey. Engineering a smart business model and strategy to preserve these tunnels from age and decay is essential. By in large, tunnels have proved their ability to stand the test of time, although many show signs of aging. The U.S. Federal Transit

Administration (FTA) released a report stating that 28 percent of transit underground structures are in substandard or poor condition.

Ongoing maintenance is needed to prevent expensive overhauls down the road.

The FHWA and FTA together developed a tunnel management system in 2002 that was intended to extend tunnel service life and reduce operating expenses. Many tunnel owners had such policies in place, but prior to this plan there were no national guidelines. In addition, the DOT emphasizes that whether the tunnel is intended for highway or transit purposes, a similar tunnel management system must be in place.

Perfecting the Field

There is a growing team of engineers who belong to the Virtual Team on Road Tunnels (VTRT). This group, created through the FHWA, was developed to expand a network of engineers well versed in the intricate planning of tunnels and to promote road tunnel engineering principles, technology, and maintenance practices.

Goals of this group include forming a national team of road tunnel experts, developing and maintaining a Web site to include a database of ongoing tunnel projects and related publications, and promoting the development of tunnel knowledge. VTRT is in existence to serve the offices of FHWA, state highway agencies, and local governments in their planning stages. Although tunnel development improved dramatically throughout the 19th century and notably in the years since the turn of the century, the process of building tunnels remains so complex that its progress has been severely underdeveloped in comparison to traditional transportation models.

Unique Safety Considerations

Even with the best planning, setbacks can occur when building tunnels. Engineers often encounter unexpected obstacles such as weak soil beds and zones, fault lines, groundwater, water pressure issues, excessive heat, and toxic gas. Gas, carbon monoxide, and smoke production from fires in tunnels are serious dangers when construction is occurring.

Tunnels built for cars must be equipped with ventilation devices to provide air flow should someone be trapped in the tunnel. In some cases, airtight compartments are built in for trapped personnel. Video surveillance and monitors are also frequently

used for vehicle tunnels to monitor traffic and safety conditions. Tunnels with heavy traffic may have their own operational staff.

Improved technology can account for the progress made in tunneling in the last several decades. Tunnels are expanding in size and the time it takes to create them is decreasing. Advanced imaging technology can be used to effectively evaluate the ground surrounding the location. In addition, machinery used to cut through geological materials is improving through greater capacity to cut through heavier rock and a wider range of materials to improve efficiency.

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See Also: Highway Construction and Maintenance; Highway Design and Engineering; Subway Systems; Subways/Elevated Trains; Transit Tunnels, Design and Construction of; Tunnels, Safety and Security Issues in.

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opportunities. The *Highway Capacity Manual* (HCM) developed by the Federal Highway Administration (FHWA) presents the concepts and methods for assessing capacity of different classes of roads and intersections. These are based on various traffic, road/intersection geometry, travel modes, and environmental characteristics. While the HCM can provide an indication of quality of traffic flow, flexibility in design of facilities is important to minimize unnecessarily costly capacity additions. There are many innovative solutions to maintain the capacity and utilize any unused and underused capacity. These include managed lanes, active traffic management, and pricing.

What Is Capacity and Why Is It Important?

Highway or road capacity is the maximum number of vehicles that can reasonably be expected to cross a point on a roadway during a given time period under prevailing traffic conditions and controls such as signals. It is measured in vehicles per hour per lane (vphpl). In the case of intersections, the capacity is measured as a function of delay experienced by a vehicle while crossing the intersection. Capacity can also be measured as level of service (LOS), which describes traffic conditions in terms of speed, travel time, capacity for accommodating more traffic, and so on. While "basic capacity" is the maximum volume that can pass through ideal conditions, "possible capacity" is the same in prevailing conditions that are more restricted. Many factors affect highway capacity, including lane width, shoulder width, road geometry, amount of mode mix, existence of intersections and traffic lights, weather, and presence of parking, pedestrians, and transit.

The road system is key for mobility as well as economic, social, and cultural opportunities. Road systems that function well with reasonable capacity to accommodate future growth in traffic support economic growth. This is especially true for higher classes of roads such as highways and arterials. As the traffic approaches the capacity of the road, we experience traffic congestion. Traffic congestion affects us not only in terms of delays but also in terms of lost work hours, emissions, public health, safety, and negative environmental impacts. Therefore, maintaining the capacity is considered an important aspect of transportation planning.

There are many ways to maintain the level of service. One of the most used methods is to increase

Highway/Road Capacity

Highway or road capacity is the ability of a road or intersection to accommodate traffic. It is important to maintain a certain level of capacity to support mobility as well as economic, social, and cultural

the capacity to keep up with the demand by adding more roads or widening existing roads. However, in recent years, this has been considered costly and physically nearly impossible. Other methods include managing the traffic demand by having compact and mixed land use development as well as encouraging transit and nonmotorized travel such as biking and walking. Managing the traffic on highways with the use of intelligent transportation system (ITS) tools as well as financial constraints such as tolling has seen increased interest. In order to plan, design, and operate road facilities and intersections, it is critical to understand the maximum capacity and current capacity of facilities.

Highway/Road Classification

The highways and roads in the United States are divided into different functional classes. Functional

classification is the process by which streets and highways are grouped into classes, or systems, according to the mobility and access characteristics they intend to serve. The FHWA divides roads into urban and rural, based on census designation of urban and rural areas. These are further divided into arterials, collectors, and local streets. Arterials include interstate highways, freeways, and other highways. They connect, as directly as practicable, the nation's principal urbanized areas, cities, and industrial centers.

Within urban areas, arterials are divided into principal arterials and minor arterials. These roadway categories vary based on the roadway's relationship to mobility and land access. Here, mobility is defined as the ease of movement between points, whereas land access is defined as the access to specific property. Arterials emphasize a high



Looking at a typical two-lane road in New Delhi through a vehicle windshield shows the need for infrastructure improvement. Developing nations around the world are quickly outgrowing existing road capacity, impeding both the economy and the environment. In Mumbai alone, between 1991 and 2005, passenger vehicles increased by 420 percent and taxicabs by 125 percent.

level of mobility for through movement, whereas local streets emphasize the land access function. Collectors offer the middle path—relatively equal importance to mobility and land access. There are overlaps of function and mobility characteristics between different categories. All functional classes are expected to perform within a desirable range of capacity conditions. In order to understand the performance of an existing road or to design a new facility, it is important to develop methods to calculate capacity of the facility.

Highway Capacity Manual and Other Tools

In the United States, the Transportation Research Board (TRB) publishes the *Highway Capacity Manual*, which contains concepts, guidelines, and computational details for calculating capacity and quality of service for road segments and intersections. These calculations take the number of vehicles, road/intersection geometry, traffic controls, on-street parking, transit, pedestrians, and bicycles into consideration. The first HCM was published in 1950 and attempted to quantify the concept of capacity as a response to the rapid expansion of the U.S. roadway system after World War II.

The level of service concept and transit was introduced in the 1965 version (HCM2), and the 1985 version (HCM3) added pedestrians and bicycles into the fold. The 2000 version (HCM4) refined the methodologies using the latest research available and expanded its depth. The 2010 version (HCM5) made substantial revisions to and reorganized the materials. The HCM5 describes methodologies for noise, air quality, economic, and multimodal planning analyses.

The HCM allows for analysis of capacity on points (for example, intersections), segments (for example, road length between intersections), facilities (an aggregation of points and segments), corridors (parallel freeways and arterials), and areas and systems. It takes into consideration all modes, including automobile (passenger cars, trucks, buses, recreational vehicles, and motorcycles), transit, pedestrians, and bicycles. Measures can be calculated for both uninterrupted-flow facilities (access-controlled highways) and interrupted-flow facilities (where signals and stop signs interrupt the traffic flow).

The HCM uses level of service as the measure of capacity and divides traffic movement on roads and intersections into six categories: A being the

best and F the worst. The HCM calculations present vehicular delay in seconds, a ratio of volume to capacity (v/c ratio), and number of vehicles or length of a queue. The delay is then converted into levels of service. LOS A represents a free-flow operation: vehicles are almost completely unimpeded in their ability to maneuver within the traffic flow and travel at or above speed limit. LOS B also represents a reasonably free-flow operation: the ability to maneuver within the traffic flow is slightly restricted but traffic can still travel at speed limit. LOS C represents a stable traffic flow with speeds near or at free-flow speeds of the highway/road: the ability to maneuver within the traffic flow is noticeably restricted. LOS D represents speeds that begin to decline with increased density and approaching unstable flow: the ability to maneuver within the traffic flow is noticeably restricted here, too, with speeds dropping below the limits. LOS E represents operations at its capacity: vehicles are closely spaced within the traffic stream and there are virtually no usable gaps to maneuver. Since it is already an unstable flow, any incidents could severely disrupt the flow. LOS F represents a breakdown of traffic flow: there will be queues forming behind the point of breakdown.

Similar LOS categories are used for intersections as well, with LOS A being the best and LOS F the worst. LOS A is assigned when there is a less than or equal to 10-second delay, while LOS F is assigned when there is more than or equal to 80-second delay for signalized intersections and more than or equal to a 50-second delay for unsignalized intersections. Later versions of the HCM also included analysis of roundabouts, as there had been an increase in the use of roundabouts as an intersection traffic control in the United States.

There are tools other than the HCM for measuring capacity. Sketch-planning tools produce general order-of-magnitude estimates of travel demand and system performance. Microscopic simulation models simulate movement of individual vehicles based on deterministic relationships of flow, speed, and density of traffic. Hybrid models employ both macroscopic and microscopic models to analyze very large networks. The choice of model depends on the objective, geography, facility, traffic conditions, and other factors of analysis, model capabilities, data availability, as well as user interface and ease of use.

Need for Flexibility

Even with all these sophisticated tools for measuring capacity, caution is required to make final decisions. There is variability in traffic conditions from place to place and in different environmental and social conditions. These changes can make significant differences in what is accepted as a good quality travel experience. It is important to understand that the LOS and other capacity measures are only indicators, not absolute values to be followed. The design or reconfiguration of roadways and intersections should also consider other aspects, such as quality of life, pedestrian and bicycle comfort, aesthetics, and environment, among others.

Potential future traffic demand is calculated using sophisticated forecasting models. However, due to the variability of factors such as economic conditions, changes in vehicular and traffic control technology, travel mode preferences, and fuel price, the travel patterns could change in short time periods. This could easily translate into wrong forecast numbers. If designers consider LOS as absolute criteria to be met in road design, any increase shown by models will need to be met to sustain capacity. This could result in costly physical expansion such as extra lanes on segments or turn lanes at intersections. Such expansion could also mean degrading environmental features. Therefore, any capacity calculations for future scenarios must consider other qualitative aspects as well as be flexible.

Innovative Solutions for Increasing Capacity

There are many new solutions being explored and implemented to increase capacity without getting into costly physical expansion of roads. These solutions are mostly based on operational improvements. Some of the most common solutions are managed lanes, active traffic management, shoulder use, and signal coordination. Managed lane is an operational practice utilized to address congestion and maintain capacity by controlling traffic movement on the highway. The FHWA defines managed lanes as “highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to the changing conditions.”

The managed lane concept regulates demand, separates traffic streams to reduce turbulence, and utilizes available and unused capacity. Typically, this is a freeway-within-a-freeway where a set of lanes

within the freeway cross-section is separated from the general-purpose lanes. The facility incorporates a high degree of operational flexibility so that over time, operations can be actively managed to respond to growth and changing needs. The operation of and demand on the facility is managed to achieve an optimal condition, such as free-flow speeds. The management strategies include pricing (static or variable), vehicle eligibility (for example, minimum occupancy), and access control (for example, access for all vehicles on certain segments).

Active traffic management strategies can be considered as extensions of the managed lane concept. It could change the toll price based on the demand and available capacity to maintain a certain level of service. It could also do a similar treatment for occupancy limitations or access. However, for this strategy to be successful, advanced technologies should be used and multiple agencies should coordinate their activities smoothly.

Other active traffic management strategies include variable speed limits, hard shoulder running, and ramp metering. The variable speed limit strategy allows officials to adjust the speed limit according to weather, traffic conditions, and construction. Drivers could be informed of these changes through use of variable message signs that display allowed speed on different lanes on different stretches of the highway. Other advanced traveler information systems (ATIS) also could be employed. Hard shoulder running allows for use of shoulders as auxiliary lanes during extremely congested travel conditions.

Such shoulder running can also be activated for incident management. A variation of the same concept is to allow transit buses to use the shoulder to move ahead of auto traffic without getting caught in the congestion. Ramp metering is aimed at reducing the volume of traffic entering the highway. Traffic signals stop the traffic on ramps that are entering into the highway. The stored traffic will then be allowed to enter the highway during gaps in mainline traffic. The traffic on the mainline as well as on the ramp is detected using sensors and used in algorithms to calculate the release rate and time. Traffic signal coordination can improve the capacity on urban arterials and collectors. Signals are usually stand-alone and look at traffic entering the intersection from their respective approaches only. However, signal controllers for adjacent intersections

could be coordinated using technology to allow smoother flow of traffic along a corridor. Such innovative methods contribute to better management of traffic and utilize maximum possible capacity.

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See Also: Advanced Traveler Information Systems; Automated Traffic Control Systems; Federal Highway Administration; High Occupancy Toll Lanes; High Occupancy Vehicle Lanes; Intelligent Transportation Systems; Traffic Flow; Transportation Research Board; Travel Pricing.

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Highways, Rural and Low-Volume

While definitions vary, rural land occupies roughly 83 percent of the United States. For the purposes of highway classification and planning, the U.S. Department of Transportation (USDOT) defines rural to be a nonmetropolitan area outside the limits of any incorporated or unincorporated city, town, or village.

Rural and low-volume highway planning and policy is decided in a manner that benefits the rural communities these roads impact. In 1999, the USDOT announced the Rural Transportation Initiative to allow these communities to share in the economic and social benefits that many USDOT programs provide, including safety and infrastructure. The initiative gives those in rural America a chance to participate in the planning that shapes their transportation systems.

Characteristics of Rural Highways

Rural roadways are divided into three categories: basic rural, developed rural, and urban boundary rural. Basic rural traditionally does not have more than 5,000 residents near the city center and upgrading roads or access to public transportation is costly. Developed rural includes regions that do have populations reaching over 5,000, yet despite the apparent need in many areas, funding is still difficult to come by to improve road conditions. Urban boundary rural regions neighbor metropolitan, populated areas and the travel conditions vary greatly.

The population of rural communities has continued to dwindle in the United States as people move out of rural communities to urban areas with stronger economic prospects and employment opportunities. Likewise, services such as local stores have disappeared or moved from mid-sized communities to larger shopping centers. Because of the declining population, the Federal Highway Administration believes rural communities are generally supportive of transportation improvement projects to promote economic growth and development in the rural region. Some areas, however, are not supportive of such projects because they do not want spillover from neighboring urban areas and wish to leave the character of the rural region intact.

Safety Concerns

Low-volume roads and highways offer unique challenges, including long distances between population centers, steep grades, mountain passes, and extreme weather conditions. Low-volume highways consequently have long distances between population centers, deficient roads in many areas, and high vehicle speeds. For this reason, the fatality rate of rural highways is twice the average for urban roads. It often takes a longer time for emergency response personnel to arrive to an accident scene due to these long distances.

Economic Planning

Rural populations are widely dispersed, making their planning all the more important. Highway network planning not only connects rural citizens to jobs, health care, food, and family but also brings consumers, such as tourists, to the region to support the local economy. The vast majority of all goods nationwide are shipped into and out of states by truck because of the flexibility and door-to-door



A rural highway runs through Marshall County, Indiana, in 2005. One problem facing rural highway planners in some areas, such as near the U.S. borders with Canada and Mexico, is increased truck use of roads that were not built to handle such traffic. In some of these areas, the volume of truck traffic using rural road networks has grown by as much as 80 percent since 1994.

service provided by trucks. For this reason, the size of the trucking industry and reliance on highways remains large in the United States.

Rural economies were often based on occupations such as farming, mining, and forestry. These industries play a major role in highway planning, as the highway network is largely how products are exported. The agricultural sector is changing in many respects, as well. For instance, livestock production is now focused on higher productivity and this results in increased truck traffic in locations that previously never faced this problem. In addition to transporting goods, tourism and recreation create new travel demands, particularly among rural communities. Attractions such as state parks, lakes, waterfalls, ski lodges, mountains, and rivers create high traffic, depending on the season.

Lack of Funding

Although the initial building of interstate highway infrastructure is typically provided by the federal

and state governments, the maintenance of such highways is the responsibility of the local municipalities. Funding for low-volume road maintenance and preservation is difficult to provide, causing many of these highways to deteriorate. The local governments supporting these highways simply do not have the funding or the means to generate the necessary tax revenue. Forty percent of rural roads in America are inadequate to drive on.

The issue of funding also prevents the expansion of rural highways. Despite relatively smaller and less dense populations, increases in traffic often outpace the capacity of local highways. The cost of expansion, however, is high, and these projects very often get lost when in competition with highways of state and national significance.

Examples of this can be found along the Canadian and Mexican borders, where truck traffic in rural areas has greatly increased—by as much as 80 percent in some areas since 1994. However, it remains difficult to come by the funding to expand these highways.

Planning for Low-Volume Highways

As with planning of any highway infrastructure, planners of rural highways must consider the current state of the roadways, what the desired result is, and how that can be achieved. Planning for the multimodal system means taking into account not only the needs of local agencies but also state and national goals. Plans must be coordinated and comparable with different levels of government in addition to land use plans and transportation plans. Most local governments have land use policies, although these may lack a transportation component, making it difficult to cross-reference in the planning stages. Finally, having highly qualified personnel on the job is key. State departments of transportation (DOTs) do not always have staff who are specially trained or have highly technical expertise in areas such as forecasts, pavement condition analysis, and traffic and accident statistics.

Planning approaches can be locally led, state led, federally led, or take a mixed approach. In all instances, the needs of each government entity must be evaluated. Responsibilities of the state DOT in the planning process include addressing needs of both state and local communities.

In basic rural communities, planning needs are primarily focused on preserving and maintaining the current system rather than on expanding and building new infrastructure. For developed rural areas, there is an increased focus on forecasting and on finding ways to fund improvements in sporadic areas of high traffic growth. Planning needs for urban boundary rural regions can be described as having a need for growth management. In these regions, a balance between economic development and preservation must be struck.

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See Also: Historic Transportation Facilities; Rural Transportation Mobility; Scenic Roads and Parkways; State Highway Planning and Finance.

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Highways, Social and Economic Impacts of

The Interstate Highway Act was passed in 1956 to advance the development of new highway infrastructure, which has served an important function in transforming human society and affecting population dynamics. The social and economic impact of highway systems is vast and complex. This article summarizes the impact (positive and negative) of highway systems; the theoretical explanation of those impacts on economic growth, population, and employment change; and altered sociodemographic structures, as well as the temporal and spatial variations of the impact.

Highway systems have both positive and negative impacts. The positive impact includes induced economic growth and development, decreased traffic congestion, increased travel safety, and more efficient use of existing roads. These positive consequences are often cited by governmental decision makers when they argue for the construction of highways.

In the opposition, environmentalists and local communities have often protested ardently against highway construction based on the potential negative effects of highway construction, for example, disparities in highway access, spatial mismatch, less frequent family interactions, and transportation-related stress.

The Roles of Highway Infrastructure

The complex impact of highways can be better understood by looking at the societal and economic roles of these highways. As the literature on the subject has been published in several disciplines

(for example, geography, sociology, economics, and urban and regional planning), theoretical and empirical approaches to describe the social and economic impacts of highways are diverse and represent many perspectives. Such diversity in the literature also leads to a variety of definitions and explanations regarding the function of highways in society and economy. The three regional economic theories that explain the impact of highways most soundly are neoclassical growth theory, growth pole theory, and location theory.

According to neoclassical growth theory, highway infrastructure provides input into the production process and thus augments the productivity of other inputs, such as labor, but also attracts workers as a household amenity factor. The explanation and prediction of metropolitan development after the highway network is built, according to neoclassical growth theory, is insightful.

Growth pole theory explains investments in highway construction as a catalyst for change, though it concedes clearly that simply improving a highway is neither a necessary nor a sufficient factor for bringing about growth in its surrounding areas because economic decline can also be a result (that is, backwash). Growth pole theory lends itself to forecasting economic growth for decision makers, because it can pinpoint how limited resources should be allocated in a region in order to ensure economic growth and development.

In location theory, highway infrastructure aids the flow of raw materials, capital, finished goods, consumers, and ideas between central locations and their surrounding neighborhoods. The strength of location theory lies in the interpretation of the geographic distributions of human settlements; for example, central place theory, which is a specialized branch of location theory, explains the polycentric city model powerfully.

Although scholarly definitions of the particular role of highway infrastructure vary depending on their regional economic theory, they are in agreement that highways significantly impact regional economic growth and development. Each interpretation of the role of highway infrastructure has merits.

Economic Growth or Decline

Empirical studies demonstrate that interstate highways have significant influence on economic growth and development as they boost travel and

improve accessibility. Most of these studies either measure highway impact on economic activity at a macro level (for example, national or state level) typically based on growth theory, or investigate the economic impact of infrastructure investment at a local level with the help of firm location theory. Both of the two directions of study have resulted in distinct and sometimes contradictory conclusions.

For example, some studies attribute significant augmentations of output, economic growth, and wage structures to public infrastructure, whereas other studies found other factors to be far more important than public infrastructure for explaining economic growth. Establishing the actual impacts of interstate highways on economic growth and development is a complex task, first because the evidence can be interpreted in vastly different ways, and second because so many factors besides highways impact economic growth and development.

Population and Employment Change

Highways bring about changes related to population and employment in at least four ways. First, residential housing in rights-of-way must often be removed, triggering a direct decline in population size in local communities. Second, their impact on economic growth or decline triggers further change for population and employment. Third, improved highways provide access to additional employment opportunities within reasonable distance for a commuter or shorten existing commutes, saving employees time and/or money. Fourth, new highways create new employment opportunities, particularly in occupations of service such as automotive service stations, lodging accommodations, retail strip malls, and eating establishments.

Altered Sociodemographic Structures

Highways also influence sociodemographic structures significantly through at least four ways. First, a highway's impact on economic development can further lead to augmented residents' socioeconomic status and give them access to a wider variety of employment opportunities. Second, highways may change how industrial and occupational distributions are spread throughout local communities, affecting the existing social structure. Third, as the improvement of highways provides access

to more and different social institutions (such as schools and hospitals) and cultural opportunities, housing prices are influenced by the associated accessibility premium.

Moreover, highways could lead to segregations, by race and/or income. In environmental justice and social inequality literature, highways are interpreted as unfavorable infrastructure as they bring environmental pollution such as noise, dirt, and fumes to the right-of-way and nearby communities. In urban areas, highways also create “crime” spaces that people avoid. Thus, the reduced livability lowers the land values and real estate values of immediate neighbors, often causing so-called white flight. Resulting vacancies are more likely to be filled by minorities.

In addition, studies have shown that the presence of disproportional minorities increases the likelihood that unfavorable facilities may be built in an area and that environmental injustice is a consequence of discriminatory siting practice. The argument surrounding unfair siting selection is parallel to some historical ones regarding highway construction used as a tool to separate minority communities from white communities in the first half of the 20th century.

Variation of the Impact by Stages of Highway Construction

Experts in demography and regional economics often claim that the relationship between highways and economic growth resembles the question about the chicken and the egg: a relationship of mutual influence with feedback effects. While a highway of higher quality stimulates travel and economic growth, the resulting travel and economic growth lead to the demand for even better highway access.

Since the development of new highways is a process of several (if not many) years before the public can fully take advantage of it, the question arises as to how the economic impact varies in different stages of highway construction, namely, in the preconstruction stage, the construction stage, and the postconstruction stage. Most research tends to conclude that economic and population growth are the causes for highway construction in the preconstruction period.

During actual construction, however, the construction is the cause for economic and population

change because decisions have already been made and the highway construction is in process. Once construction is finished, highways further advance economic and population growth.

Spatial Variation of the Impacts

The social and economic impacts of interstate highways vary in rural, suburban, and urban areas. In rural areas, highways substantially influence living conditions; accordingly, rural development efforts often rely heavily on highway infrastructure as a major tool. Areas that were previously considered too distant from a metropolis can be within a reasonable commuting range thanks to an improved highway.

This in turn can increase rural population through added employment opportunities in or near the surrounding rural areas. Most studies on nonmetropolitan counties have revealed positive effects of interstate highways on economic and population change as they attract migrants and foster employment growth.

In suburbs, the impact of interstate highway investment is also mostly positive on general development and population growth. Suburbs in metropolitan areas grow because suburban life offers important benefits over central city life. For example, the central city may struggle with congestion, spatial economic squeeze, and residential deterioration. Consequently, the availability of modern highways hastens a tendency to move outward to fringe areas surrounding the city. Though the new highways may not directly cause this tendency, they offer a better connection between the suburb and the economic center of an urban area. Improved highways shorten commuting times to and from work.

In urban areas, the relationship between interstate highways and economic and population growth is of a more complex nature than in rural areas. The net effects of highways cannot be easily predicted there. They may aid or prevent development, always depending on many other factors, the net effects of spread and backwash, and the scale effect. For example, among immediate neighborhoods, interstate highways are considered a disamenity, while neighborhoods just a few blocks farther will see them as an advantage.

In summary, the social and economic impacts of highway systems are complex. It is suggested

readers consider a variety of perspectives of highway systems as discussed above.

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See Also: Economic Development; Employment Location; Highway Design and Engineering; Social Equity and Discrimination in Transportation; Transportation, Economics of; Urban Sprawl Versus Compact Development.

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Historic Transportation Facilities

One of America's earliest transportation images is Paul Revere riding his horse to warn patriots that the British were coming, while 21st-century transportation imagery boasts superhighways, supersonic jets, and the probabilities of commercial space travel. Although the nation has progressed light-years from the era of horses, canals, steam engines, Model Ts, and monoplanes, artifacts from the transportation past still dot the landscape, some recycled and some repurposed. Barges still ply a few of the old canal networks and pioneer roadways such as the Lincoln Highway and Route 66 have been incorporated into existing highway systems. Abandoned railroad beds have been repurposed into recreational trails. Rockets leave vapor trails in the sky as they speed toward the stratosphere, while airplanes belonging to Wilbur and Orville Wright and Charles Lindbergh are displayed in the National Air and Space Museum.

Canals

Canals have played an important part in American transportation, and thousands of them still operate as part of the U.S. maritime grid. Built between 1817 and 1825, the Erie Canal runs about 363 miles from the Hudson River in Albany, New York, to Lake Erie at Buffalo, New York. Containing 36 locks, the Erie Canal provides a navigable water route from the Atlantic Ocean to the Great Lakes.

The Erie Canal was the first transportation system between New York City and the Great Lakes that did not require portage; using the waterway instead of wagons to move freight cut transport

costs by about 95 percent. The Erie Canal stimulated a population explosion in western New York State, opened midwestern regions to settlement, and elevated New York City to the chief port in the United States. Between 1834 and 1862, the Erie Canal was enlarged, but in 1918, the larger New York State Barge Canal replaced it. Today, the Erie Canal is part of the New York State Canal System.

In 2000 the U.S. Congress designated the Erie Canalway a National Heritage Corridor to recognize its national significance and its place as one of the most important civil engineering and construction accomplishments in North America. Commercial traffic increased on the Erie Canal in 2008, but recreational boats still provide most of its traffic load.

In 1823, the state of Illinois created a Canal Commission to oversee the design and construction of the Illinois and Michigan Canal, finished in 1848 at a cost of \$6.5 million dollars. The Illinois and Michigan Canal furnished the first complete water route from the East Coast to the Gulf of Mexico by connecting Lake Michigan to the Mississippi River through the Illinois River. The canal begins at the Chicago River's south branch at Bridgeport and extends 96 miles to the Illinois River at LaSalle. Mules and horses toiling along the tow paths pulled the barges that composed the canal's commercial traffic.

With the completion of the Illinois Waterway in 1933, the Illinois and Michigan Canal was closed to navigation but was soon developed for recreation. Visitors can follow the Illinois and Michigan Canal State Trail along the old tow path from Rockdale to LaSalle along 61.5 miles of scenic views of the Des Plaines and Illinois Rivers. Numerous state parks, historical sites, and abundant wildlife as well as distinctive landscapes line its banks. Interpretive programs and information centers are located at key places along the trail.

Railroads

As the major corporations of the 19th century, railroads brought sweeping social, economic, and political change to the United States. They sparked a building boom of bridges, depots, and towns and allowed ruthless rail magnates and magnificent steam locomotives to rule the country.

Railroad names like the Baltimore & Ohio, the South Carolina Canal and Rail Road Company, and the Mohawk & Hudson Railroad became familiar to Americans. One of the greatest technological

advances of the time occurred at Promontory Summit in the Utah Territory, when the Central Pacific Railroad, starting in San Francisco, California, and the Union Pacific, starting in Omaha, Nebraska, met there on May 10, 1869, linking the eastern and western coasts with slender, steel rails. By the 1930s, the railroad companies had built an efficient transportation network that crisscrossed the country, but the advent of cars, buses, trucks, and aircraft provided cutthroat and ultimately decimating competition. The amount of track in the United States peaked at 254,261 miles in 1916, but by 2007 it had declined to 140,695 miles.

Steam Locomotives

Steam locomotives evolved along with railroads. Originally used to haul coal and other materials, railroads quickly adapted steam engines to haul passenger trains. Steam engines became larger, more powerful, and faster, their two-cylinder



A marker stands at the site of the western terminus of the Lincoln Highway in San Francisco's Lincoln Park. A street sign also marks the highway's starting point in Times Square in New York.

design expanding to four cylinders. Companies added gears to locomotives that operated on industrial, mining, quarry, or logging railways. From the 1930s to the 1950s, diesel and electric trains gradually replaced steam locomotives.

In the 21st century, steam locomotives are used for historical, educational, or entertainment functions. Railroad museums feature exhibits built around the history of steam engines, including the preserved and operational steam locomotives themselves. Many museums and railroad societies offer steam engine trips, including Steam Town in Scranton, Pennsylvania, and the Pacific Southwest Railway Museum in Campo, California.

Rails-to-Trails

A 1960s rails-to-trails movement to convert abandoned or unused rail corridors has grown into a social and ecological network. Once unused tracks disappeared, people started walking the old grades, socializing and discovering the countryside. In the winter, they skied or snowshoed the corridor. Half a century later, 15,000 miles of rail trails and over 100 million users a year contribute to the national trails system.

The 237-mile Katy Trail stretches across most of Missouri, with over half of it following the path of Lewis and Clark up the Missouri River's towering bluffs. It is America's longest "rail to trail" route, following the former Missouri Kansas Texas rail line. After it leaves the Missouri River, the trail winds through farmland and small towns, providing ideal terrain for hiking, running, cycling, and horseback riding on the Tebbetts-Portland section.

Moving Down the Highway

Henry Ford did not create automobile technology, but he did perfect and popularize it by introducing the assembly line in automobile manufacturing and offering a \$5-a-day wage that he hoped would increase worker productivity and encourage those workers to use part of their earnings to buy a new car. These innovations helped make the automobile accessible to the American public. By the end of the 1920s the number of registered drivers had reached 23 million, despite the fact that they could only order Ford's Model T in black at a cost of \$490. In 2007 the U.S. Department of Transportation estimated that there were 254.4 million registered passenger vehicles in the United States.

When Henry Ford commercialized the automobile in the early 20th century, the United States already possessed a network of auto trails often marked and maintained by organizations of private citizens. The National Road, the Lincoln Highway, the Dixie Highway, and Route 66 are just a few of America's vintage roads that connect the present with the past.

In 1806 Congress passed an act creating the National Road and President Thomas Jefferson signed the act into law, allowing for a road connecting the Atlantic Ocean and the Ohio River. Historically known by various names, including the Cumberland Road, National Pike, and Western Pike, the National Road eventually ran approximately 800 miles from Baltimore, Maryland, through Pennsylvania, West Virginia, Ohio, and Indiana, officially ending at the old statehouse in Vandalia, Illinois. With the advent of the Federal Highway System in the late 1920s, the government folded the National Road into its design for U.S. Route 40. In the era of the transcontinental and interstate highway systems much of Route 40 disappeared into state highway systems, with Interstate Highways 70 and 68 paralleling the National Road, although a careful scrutiny of the roadway still reveals traces of earlier paths.

The Lincoln Highway Association maintains the Lincoln Highway, which stretches from Times Square in New York City to Lincoln Park in San Francisco, and at times in its history passed through 14 states, 128 counties, and more than 700 cities, towns, and villages. Formally dedicated October 31, 1913, the Lincoln Highway is a national memorial to President Abraham Lincoln and one of the first automobile roads across America, bringing economic prosperity to the places it touched. It wends its way through historic places, several national parks, and a few major cities.

Although it has been reconfigured over its 100-year life span and parts of it have been incorporated into state and interstate highway systems, much of it as U.S. Route 30, remnants of the Lincoln Highway still exist across America. In 1992, the Lincoln Highway Association reformed with the mission of identifying, preserving, and improving access to the Lincoln Highway. The Lincoln Highway is on the National Register of Historic Places, and motorists from all over the world drove vintage automobiles along it to celebrate its centennial in June 2013.

The Lincoln Highway inspired the slightly younger Dixie Highway. In 1914, the Dixie Highway Association planned for this road to be part of the National Auto Trail system connecting the U.S. Midwest with the southern United States. Constructed and expanded from 1915 to 1927, the Dixie Highway evolved into a network of connected paved roads instead of a single highway. In 1927, the Dixie Highway Association disbanded and the Dixie Highway became part of the U.S. Route system, with some part of it converted to state roads. Several states continued to identify the “Dixie” or “Old Dixie” Highway.

By the late 1920s, a system of numbered U.S. highways replaced the auto trails, and Congress passed the Federal Highway Act of 1921 to further establish a network of roads. U.S. Route 66, affectionately known as the “Main Street of America,” was one of the original numbered highways. Established on November 11, 1926, Route 66 originally ran 2,448 miles from Chicago through Missouri, Kansas, Oklahoma, Texas, New Mexico, and Arizona to its destination in Los Angeles, California.

Communities along Route 66 became prosperous as the highway increased in popularity and Route 66 went through many improvements and realignments until June 27, 1985, when the U.S. government removed it from the U.S. highway system after replacing it with newer roadways in the Interstate Highway System. The U.S. Department of Transportation designated Route 66 a National Scenic Byway, renaming it Historic Route 66, and several states have incorporated bypassed sections of the old highway into their state road networks, calling it State Route 66. People have restored gas stations, motels, and other businesses along the old Route 66, and every year—maps in hand to make the right connections—people from all over the United States and the world motor the original Route 66.

Airplanes and Spaceships

On December 17, 1903, at Kitty Hawk, North Carolina, Wilbur and Orville Wright flew the first heavier-than-air machine in a controlled, sustained flight with a pilot aboard. Designed and built by the Wright Brothers, who solved the basic problems of mechanical flight (lift, propulsion, and control), the Wright Flyer’s longest flight measured 852 feet and lasted 59 seconds.

World War I aviation technology, Colonel Billy Mitchell, and Charles Lindbergh advanced the

cause of aviation during the 1920s and 1930s. Air power dominated World War II, and technological advances in aviation after World War II ushered in the jet and space ages. The Yankee Air Museum at Willow Run in Belleville, Michigan, houses a Willow Run bomber and other World War II airplanes, and the Smithsonian Institution’s National Air and Space Museum in Washington, D.C., displays the Wright Flyer and Charles Lindbergh’s *Spirit of St. Louis*.

The 21st-century space age features National Aeronautics and Space Administration (NASA) solar system missions, and NASA’s Voyager 1 space probe is speeding 11 billion miles from Earth and will soon explore interstellar space. Back on Earth, companies like California-based Space Exploration Technologies Corporation are researching the parameters of commercial space travel, and the U.S. Astronaut Hall of Fame in Titusville, Florida, displays astronaut Gus Grissom’s MR 4 space suit as a reminder of the price of the transportation revolution.

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See Also: Automobile Culture; Cable Cars; Ferries; Funicular Railways; Recreational Travel; Scenic Roads and Parkways; Space Travel, Commercial; Train Stations, Economics of.

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Hitchhiking

Hitchhiking as a form of transportation involves the solicitation of free rides from passing motor vehicles at the side of a road, normally from strangers (although hitchhiking can occasionally involve other forms of vehicles). Also referred to as thumbing, autostop, trampen, or hitching, hitchhiking is

variously seen as an economic necessity, a means of escape or adventure, a sustainable mode of travel, and a way of overcoming a lack of public transit. To request a lift, it is commonplace for hitchhikers to extend an arm toward the road, with a raised thumb and clenched fist, or to present a sign or placard with the desired destination or route clearly visible to passing vehicles—although this form of signal is most common in Europe and the United States. A journey achieved by hitchhiking often involves more than one ride.

Hitchhiking became popular in the 1920s following the emergence of the automobile. Since the 1970s, however, the practice of hitchhiking has generally seen a decline in popularity as a result of the risks and dangers that have been associated with sharing a car with strangers—both for the hitchhikers and for the motorists who pick up hitchhikers—although there have been calls to revive it as an alternative mobility and more eco-friendly form of transport.

Hitchhiking is often associated with the emergence of social inequalities. For example, in times of economic necessity, such as the Great Depression, hitchhiking was a common form of transportation and a necessity for Americans migrating in search of labor. During this time, picking up a hitchhiker was considered a civic good or duty. Similarly, in Cuba, a shortage of cars as a result of the collapse of the Soviet Union and the U.S. trade embargo made hitchhiking an ordinary cultural practice and requirement. It continues to be encouraged by the Cuban government as a means to address the shortage of transportation and ease pressures on an overcrowded public transit system. Any government vehicle with room for another passenger is required to stop by law (although this only applies if the hitchhiker is a Cuban national).

Safety, Fear, and Security

Much of the decline in hitchhiking has been attributed to its perceived dangers, although there have been efforts to connect its decline to a rise in the provision of affordable public transit—a connection that has largely been discredited. In the United States in particular, high-profile antihitchhiking campaigns in the 1950s by public relations firms, insurance companies, government agents, and sections of the media positioned the hitchhiker as a potential threat to motorists. For instance,

campaigns by the Federal Bureau of Investigation (FBI) encouraged drivers to avoid hitchhikers to ensure their personal safety and protect themselves from potentially violent strangers.

While these campaigns raised questions about the safety of picking up hitchhikers, high-profile cases of attacks on hitchhikers highlighted the danger of hitchhiking not only for motorists but for hitchhikers as well. This was particularly the case for female hitchhikers who were considered to be vulnerable to attacks by male motorists and therefore were targeted by awareness campaigns that aimed to encourage other forms of travel. In some instances, this led to the creation of female-only hitchhiking networks, where women would only travel and hitch with other women as one way of avoiding the perceived threat of unwanted male attention and violence.

Legal Status

Despite fears about the safety and security of hitchhiking, there are few places where hitchhiking is completely outlawed. There are no restrictions in Europe, although the extent to which hitchhiking is considered culturally acceptable varies from country to country. Similarly, in the United States, the acceptance of hitchhiking is dependent on local governments. There are, however, restrictions on where hitchhikers can solicit rides. This includes prohibition on all roads where pedestrians are banned, including motorways, interstates, autobahns, and road shoulders in Australia. However, the degree to which laws are enforced is variable.

As a result of restrictions, hitchhikers tend to occupy gas (petrol) stations, on-ramps, rest areas, service areas, toll stations, or official stops, such as the ones located around university campuses or towns, or on the edge of cities, as is the case in Cuba. Given the variability in acceptability and legislation, online communities of hitchhikers have been established to create hitchhiking maps and to swap tips, advice, experiences, and knowledge of local customs and etiquette, to help travelers locate the best sites to catch a ride and to help avoid fines. There are also many hitchhiking guides and magazines that have been established to promote hitchhiking as a nomadic, sustainable form of transport.

Hitchhiking and Youth

As a mode of transport commonly linked with economic necessity, hitchhiking is often associated

with youth and students. At the height of its popularity, areas surrounding universities and college campuses became common sites for hitching, often as a result of a lack of adequate transportation to and from campuses. In the Netherlands, official hitching spots in university towns are common, although hitching by students has declined since the introduction of free public transport for students. In the United Kingdom (UK), there is still an official hitching post on the campus of Lancaster University, which has become a tourist attraction.

Hitchhiking is also at the heart of a UK university charity fund-raising competition known as Jailbreak, which gives students 36 hours to see how far they can hitchhike without spending any money. The event is described as an adventure that relies on the powers of persuasion and “sweet-talking” to hitch a ride. It often involves hitching rides in motor vehicles, public transport, and airplanes to enable the participants to cover greater distances.

As a choice of travel, it is also considered to be a form of adventure and an expression of resistance, associated with nomadism, disorder, freedom, deviance, and youthful rebellion. This understanding of hitchhiking emerged in 1950s postwar America, when the hitchhiker was stereotypically considered to be part of a counterculture that was antiestablishment, nomadic, and engaged in political activism. Hitchhiking, for instance, was often seen as a way of escaping the suburbs, rejecting middle-class family values, and achieving new mobility outside normal economic trade relations and community attachments. This was a common representation in popular culture at the time.

Recently, attempts to revalorize the sociability of hitchhiking as an alternative mobility culture and form of community have acknowledged a rise in the organization of “hitchhiking gatherings” whereby hitchhikers travel to an organized destination to camp and exchange experiences before hitchhiking back to their origins.

The rise of hitchhiking gatherings highlights the new values that are attributed to the practice of hitchhiking as a form of travel that privileges social exchange, unexpected encounters, and a slower pace of travel.

Carpooling and Sustainable Travel

Questions have been raised about the differences between hitchhiking and carpooling schemes,

which have been growing in popularity as a more environmentally friendly way of traveling. It is generally accepted that carpooling initiatives are more likely to involve commuters and suburban residents, who arrange to share a ride with others and split the costs and burden of driving over a sustained period of time. Hitchhiking is therefore distinguished from carpooling schemes by a lack of both prearrangement or organization (with the exception of hitchhiking gatherings) and the reliance upon strangers (and thus the perception of risk involved). While hitchhiking can support sustainable transport agendas by reducing the number of vehicles on the road, greater emphasis is placed on its links to nomadism, social exchange, and adventure, and as an alternative form of mobility and cultural practice.

There is a lack of policy concerning hitchhiking and the conditions under which it might become a possible solution for transport shortage or sustainability. The lack of policy interest is largely as a result of its presumed associations with risk and insecurity. There have been calls for more regulations and more organized forms of hitchhiking, whereby lifts might be prearranged to reduce the element of uncertainty or where both drivers and hitchhikers might be registered to practice hitchhiking or to provide a ride. The use of Web sites has become a popular means to do this. However, there have been arguments about whether such forms of transportation might still be considered hitchhiking in the strictest sense.

Popular Culture and the Media

Hitchhiking has featured prominently within popular culture and the media, and it is important to reflect on the close relationship between the media and hitchhiking in order to understand the rise and fall of its popularity as a method of travel. Hitchhiking was a prominent theme in John Steinbeck's writing on the Great Depression. Novels like *The Grapes of Wrath* highlighted the necessity of hitchhiking in the search for work. Ida Lupino's *The Hitch Hiker* (1953) features a hitchhiking serial-killer who kills the motorists who offer him a ride. This film, alongside other films noir, was credited with heightening the fear associated with hitchhiking in the 1950s.

Another prominent example is Jack Kerouac's *On the Road* (1957), which follows the adventures of Sal

and Dean as they travel across the United States in search of excitement, adventure, and the exhilaration of the open road. The book depicts the resistance and counterculture associated with hitchhiking as a form of youthful rebellion in the 1950s and 1960s. Autobiographical travel books include Tony Hawks's *Around Ireland With a Fridge* (1998).

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See Also: Automobile Culture; Automobiles, Passenger; Car Sharing; Carpooling, Casual.

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Hybrid Automobiles/ Hybrid Electric Vehicles

Hybrid automobiles, or hybrid electric vehicles, are automobiles that use both a traditional fuel-burning internal combustion engine and an electric power train. Electrical power is stored in onboard batteries, which may be charged either by the internal combustion engine or (in the case of plug-in hybrids) by being plugged into a power source to draw electricity off the grid, as full-electric vehicles do. Most of today's hybrids also make use of regenerative braking in order to improve energy efficiency and reduce waste heat. Hybrids in general have better fuel economy than similar conventional vehicles and use smaller internal combustion

engines, without facing some of the disadvantages of full-electric vehicles.

In today's infrastructural landscape, the main disadvantage of an electric car intended for mass production is the need to recharge the automobile's batteries. While this may be possible at home—and even then, apartment dwellers among others may have difficulty recharging at home—it is far more difficult on the road, and except in California, recharging facilities are not common at U.S. gas stations.

Many hybrid cars use a start-stop system, which reduces the amount of time the engine spends idling by automatically shutting off the internal combustion engine when the car is stopped (such as in heavy stop-and-go traffic, in line at drive-throughs, or at traffic lights). Originally introduced for conventional internal combustion engine vehicles in the 1970s amid concerns about volatile gasoline prices, start-stop systems have become more common in hybrid vehicles. In particular, this improves fuel and energy efficiency in city driving, which is typically the least efficient mode of driving. Powered features like onboard radio and climate control are usually designed to run off the electric motor rather than stopping and starting with the engine.

While many drivers have absorbed the idea that every engine start induces wear on the engine, this is really only significantly true of cold starts (when the car has been stopped long enough for the engine to cool down), especially in cold weather. The short stops of a start-stop system do not weather the engine in the same way, as the oil that lubricates it has remained warm.

On the other hand, batteries do wear out faster when a start-stop system is used, especially the absorbent glass mat (AGM) lead acid batteries used by most automobile manufacturers—but even so, replacing a battery thus worn down is a much cheaper proposition.

Mazda in 2011 introduced an improved stop-start system, the i-ELOOP, which determines which piston in the internal combustion engine is in position for the fastest restart of the engine, resulting in a restart time of less than half a second, and which while decelerating into the stop converts kinetic energy to electricity that is stored in a double-layer capacitor that powers the car's electrical system during the stop period.

Some hybrids have been called "electric assist" vehicles, or mild hybrids, because they lack a mode

of propulsion that depends only on electricity, requiring the use of the internal combustion engine for that. The electric motors in mild hybrids are small and replace the starter and alternator of the conventional design, improving the car's efficiency and making a start-stop system possible. Though regenerative braking is often used, it recovers far less energy than in full hybrids, and in general the fuel efficiency gains of a mild hybrid design are, as the name indicates, mild. Honda's Integrated Motor Assist feature is an example of a major manufacturer's mild hybrid design, as is the discontinued hybrid version of the Chevrolet Malibu.

Mild hybrids use motor-generators, power transducers that are also used by many other hybrid designs. Most manufacturers have developed proprietary motor-generators for use in their vehicles, with mild variations on the same fundamental design principles, such as Toyota's Hybrid Synergy Drive. All such drives are electrical generators that can also function as motors. In the case of mild hybrids, their motor power is limited and powered by electricity generated by the internal combustion engine while it is in use.

Regenerative braking is a popular feature in hybrid cars and greatly assists in their energy efficiency and emissions. All braking systems work, by definition, by reducing the kinetic energy of the car's forward motion. Conventional automobile brakes accomplish this by friction. Applying friction increases the amount of necessary force required to turn the wheels, which then slow down much faster than if the car were to simply coast to a stop (slowed by the friction of its contact with the road). Excess energy is converted into waste heat. Regenerative braking instead reclaims as much kinetic energy as possible, diverting it to operate an electric motor in order to generate electricity, which is then stored in the onboard batteries. Conventional brakes are still used as well, however, because regenerative braking does not function well at low speeds, at which point friction braking does the rest of the work. Regenerative brakes also do not work to keep cars from rolling down inclines.

The use of hybrid cars has been encouraged in the United States through various means in order to reduce America's dependence on fossil fuels, America's contributions to greenhouse gas emissions, and the impact of gasoline price volatility on the American economy. A federal income tax credit was

offered from 2005 to 2010, for instance. The American Recovery and Reinvestment Act of 2009 opted to focus on infrastructure improvements rather than consumer incentives, but new legislation has added tax credits for plug-in electric vehicles. Several states (including Arizona, California, Florida, New York, and Virginia) also allow certain hybrid cars to use carpool/HOV lanes with only one passenger, based on the premise that hybrid car usage offers a fuel efficiency benefit comparable to that of carpooling. San Jose, California, formerly offered a free parking permit to hybrid vehicle owners whose cars had been purchased locally, and Los Angeles offers free parking in city-owned parking spaces for all hybrid or fully electric vehicles. Other cities have considered similar initiatives, though the 2008 financial crisis has tabled many such discussions.

Though hybrid designs were developed at the dawn of the 20th century, not until the end of the 1990s were any hybrid cars made widely available. The Toyota Prius and Honda Insight were the first major hybrids available in the United States and remain leading brands today. Though modern hybrids premiered on the Japanese market (and a larger percentage of the Japanese market is made up of hybrids), the United States has become the largest hybrid market in the world, with over 2.5 million hybrids sold by 2013.

Major hybrid vehicles in the 2010s include the Toyota Prius, Honda Insight, Cadillac ELR, and hybrid versions of the Toyota Camry, Ford Fusion, Volkswagen Jetta, and Honda Accord. Major launches have also been scheduled for a Toyota RAV4 hybrid, diesel hybrid Volvos, and hybrid versions of the Toyota Corolla, Hyundai Accent, and Mercedes-Benz E-Class.

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See Also: Automobile Engines; Electric Diesel Locomotive; Electric Vehicle Charging Stations; Electric Vehicles; Emerging Technologies; Green Transportation; Low-Emission Vehicles.

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Hydrogen Fuel

Like electricity, hydrogen is not an energy resource but an energy carrier, meaning that it stores energy that has been generated by some other means. It can be used as a fuel by means that release the energy it stores, such as through an electrochemical fuel cell or by burning the hydrogen in a combustion engine. When used for combustion, nitrogen oxides form, contributing to smog and acid rain, but this is characteristic of all combustion (in atmospheres with sufficient nitrogen and oxygen) regardless of fuel type. In other respects, hydrogen is a zero-emission fuel. Unlike fossil fuels, it does not rely on a depletable resource.

Pure hydrogen is rarely found, because as the lightest element on Earth, it rises into the atmosphere, but it can be manufactured. There is considerable interest in developing hydrogen as an alternative transportation fuel. However, the manufacture of hydrogen requires more energy than it can later provide as a fuel (a natural limitation of the conservation of energy), and involves environmental impacts the severity of which in the event of large-scale hydrogen production sufficient to significantly reduce the use of fossil fuels is unknown.

Hydrogen's energy density is low by volume but high by weight, given its lightness. It is usually compressed or liquefied for transport, delivery, and fuel use. In the current state of automotive technology, a hydrogen-burning internal combustion engine has a maximum energy efficiency of 38 percent, compared to the 30 percent of a gasoline-burning engine. This efficiency can be further increased with a hybrid hydrogen-electric design

using hydrogen fuel cells, but until there is a technological breakthrough or an increase in demand sufficient to reap the benefits of economies of scale, hydrogen fuel cells will be prohibitively expensive for use in most consumer vehicles, with a wholesale cost higher than the retail cost of many cars. Further, the purity requirements of hydrogen fuel cells are far more stringent than that of hydrogen-burning engines, which makes their operating costs more expensive.

However, a Japanese start-up company, Aquafairy, announced in 2013 plans to introduce affordable hydrogen fuel cells in 2014, based on a solid form of hydrogen. At the time of the announcement, its working prototypes were insufficient for powering a vehicle, better-suited to powering appliances during power outages or while camping, but vehicle-sized fuel cells were in the planning stages.

Hydrogen Production

Hydrogen production is a \$100 billion industry, but most of the hydrogen produced is not for fuel but rather to be consumed by other industrial-scale chemical processes, such as the production of ammonia or methanol. About half of U.S. hydrogen production is consumed by oil refining (which is one reason natural gas producers have had such an interest in large-scale hydrogen production). Most of the rest is used in the production of ammonia for fertilizer.

In the 2010s, hydrogen production capacity in the United States is about 3000 million cubic feet per day. Multiple technologies make hydrogen production possible, but about 95 percent of American hydrogen production comes from natural gas reforming. Natural gas reforming takes advantage of existing natural gas delivery infrastructure and uses some of the methane (CH_4) found in natural gas to produce hydrogen.

Usually the method used is steam-methane reforming, which uses superheated steam (over 1,300 degrees F) under pressure to turn methane into hydrogen, carbon monoxide, and carbon dioxide. More hydrogen is produced from reactions between the carbon monoxide and the steam (which itself contains hydrogen in the form of water molecules), and finally pure hydrogen is separated from the gas, removing the carbon dioxide and impurities. While the process is nearly always used with

methane, it will actually work to produce hydrogen from other substances as well, such as gasoline or ethanol.

Natural gas reforming can also be conducted with partial oxidation, which exposes the hydrocarbons in natural gas to small amounts of oxygen in order to oxidize them, producing hydrogen as a by-product. Steam-methane reforming is endothermic, meaning it requires heat (in the form of the steam), while partial oxidation is exothermic, meaning it produces heat as a by-product of its chemical reactions. It is also a much faster process of hydrogen production.

Natural gas reforming produces greenhouse gas emissions but fewer than are produced by the consumption of the fuel equivalent of the hydrogen being produced, so all other factors being equal—the greenhouse gas emissions associated with the storage, delivery, and sale of the fuels—hydrogen fuel produced in this manner is responsible for far fewer greenhouse gas emissions than fossil fuels, according to proponents. (There is some dispute about this.) Of course, hydrogen produced from hydrocarbon products like natural gas, even if cleaner in its life cycle, is still a nonrenewable fuel.

Sustainability and environmental concerns are not the only motives for proposing an alternative to oil-derived fuels, however. For those proponents for whom the appeal of hydrogen fuel is in freeing the United States of dependence on foreign oil, whether for political reasons or because of the price volatility of such oil, hydrogen fuel produced through coal liquefaction is a much improved energy source, despite the fact that the production of hydrogen by this method produces more, and worse, greenhouse gas emissions than gasoline use and refining does.

A small amount of hydrogen production uses methods independent of fossil fuels, but most such methods have not yet been implemented at the industrial scale, and in most cases there are no current plans to do so. (This is in part, though, because the country's hydrogen demand is adequately met by current production methods.) Hydrogen can be separated from water by various methods, including electrolysis or thermolysis, both of which require large amounts of heat. Electrolysis of water can be more cheaply implemented to produce hydrogen when it is performed at an industrial production facility or power plant where the production

of energy results in significant waste heat that can then be used to heat the water.

Since World War I, the ferrosilicon method of hydrogen production has been used by militaries in order to produce hydrogen to fill balloons. Water is added to sodium hydroxide and ferrosilicon in a pressure tank small enough to fit in a truck, and the resulting chemical reaction produces steam, sodium silicate, and hydrogen. More recently, experiments have been conducted on recently discovered properties of algae as a bioreactor. While experiments have suggested economic feasibility of commercial development, it has not yet been implemented.

Similarly, hydrogen can be produced by biomass, and the exploitation of biological waste to produce hydrogen has been suggested by green groups. A number of other methods have also been explored. For instance, in Spain, the Platacorma Solar de Almeria concentrates solar power to heat water in order to dissociate it into hydrogen and oxygen. The plant design is intended to be scalable.

Delivery Systems

A system of delivering energy via hydrogen is called *hydrogen economy*, a term coined in a General Motors talk in 1970 by University of Michigan professor Lawrence Jones. The term *fuel economy* refers to an energy delivery system; like gasoline, hydrogen is not an energy source itself but delivers energy when combusted or otherwise consumed. The hydrogen economy is a proposed replacement for the hydrocarbon economy, based on the argument that hydrogen use is cleaner and more sustainable.

Storing hydrogen is an important aspect of hydrogen economy. Because of hydrogen's light weight, over time it penetrates the liner of tanks used to contain it, which weakens them faster than tanks used to contain other compressed gases. The weight of the tanks used to hold compressed hydrogen also reduce a vehicle's fuel efficiency. This is less true of liquefied hydrogen, but liquefaction of hydrogen is a more energy-intensive process than compressing the gas, adding both to the financial costs of the final product and to the overall efficiency and environmental impacts.

Further, tanks of liquefied hydrogen must be extremely well-insulated and are prone to forming exterior surface ice, which accelerates corrosion. All of these problems are cited in support of

hydrogen fuel cells as an alternative to hydrogen-burning engines, but as mentioned above, hydrogen fuel cells at present are extremely expensive.

Large-scale use of hydrogen vehicles would require a hydrogen infrastructure in place. This requirement is why hybrid vehicles have been the most successful alternative to traditional fuel-burning vehicles: their difference is all in their design, but their usage is substantially the same and they do not require the support of new infrastructure. Electric cars, for instance, require access to charging stations if the driver is to drive further from home than a single charge can take him. Drivers of alternative fuel vehicles similarly need to be able to refuel their vehicles, which requires distributing hydrogen to filling stations (most practically, as an option at existing gas stations, though the more hydrogen is promoted as an alternative to gasoline the less this is in the interest of the Big Oil companies that own those gas stations).

At present, there are 23 hydrogen stations in California, only eight of which are open to the public, and a few dozen in the rest of the country. Development of hydrogen stations in the United States stalled after the 2008 financial crisis, and most 2009 federal stimulus money for alternative energy development went to other projects.

Infrastructure is repeatedly cited as the hardest obstacle to surmount. While expensive vehicles like electric cars can still be successfully launched because of the number of wealthy consumers willing to purchase, and the large payouts of those early consumers help subsidize production such that a later wave of cars may be sold at a slightly lower price, and so on until the cost of the vehicle is within reach of the general public, this is a slow process. Personal computers, for instance, took about thirty years to come down in price from impractical luxury item to something most of the working class can afford, and personal computers were not competing with an alternative product offering the same functionality at a lower price. A process that slow, or even a quarter as slow, cannot proceed at all if infrastructure does not also expand in order to allow adoption at great enough rates to bring the price down for subsequent purchasers.

On the other hand, greater fuel efficiency reduces infrastructure requirements because filling stations can be spaced further apart, and it thus takes fewer of them offering hydrogen in order to make a given

area driveable for hydrogen vehicle owners. Despite the problems facing hydrogen fuel use, at the 2012 World Hydrogen Energy Conference, many manufacturers announced plans to have hydrogen fuel cell vehicles available for sale in 2015, including Honda, Hyundai, and Toyota. Though Ford's hydrogen research projects in the past were canceled or ceased being funded, both Ford and General Motors have committed to introducing hydrogen fuel cell vehicles in 2015 as well.

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See Also: Alternative Automotive Fuels; Alternative Aviation Fuels; Alternative Fuels; Biofuels; Hydrogen Fuel Cells; Zero-Emissions Vehicles.

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Hydrogen Fuel Cells

Hydrogen fuel cells are remarkable devices that produce energy in the form of electricity through the chemical combination of hydrogen and oxygen. They have been used in industry and have powered spacecraft to the moon. Can hydrogen fuel cells power the average person's car with the efficiency and relative economy of gasoline-fueled internal combustion engines?

The fuel cell has basically three components: an anode, a catalytic membrane, and a cathode. Compressed hydrogen is let into the anode side of the cell. The anode splits the hydrogen into electrons and protons. The membrane (or electrolyte), which could be made of paper-thin gold or other metal, lets only the protons pass through. It blocks the electrons, which pass through a battery to drive an electric motor. Electrons then pass on around the fuel cell, reunite with the protons, combine with oxygen from outside

air and form water. Water is the only by-product—or emission—of the entire process.

History

By 2013, hydrogen fuel cells were thought of as one of the technologies that could break civilization free from fossil fuels. In the 1960s, the National Aeronautics and Space Administration (NASA) put fuel cells aboard Gemini spacecraft to power manned spaceflights of up to two weeks and supply astronauts with water (the by-product of energy generation). Fuel cells continued their work on Apollo moon missions and on Skylab and the Space Shuttle.

Despite that, rudimentary fuel cells have been around since 1838. That year Welsh lawyer and scientist William Robert Grove revealed his discovery that two platinum electrodes standing in sulfuric acid, their opposite ends sealed in containers of oxygen and hydrogen, would conduct a current of electricity between them. Grove himself was following up on the discovery in 1800 of William Nicholson and Anthony Carlisle that electricity could break water down into its components of hydrogen and oxygen.

Exactly how Grove's "gas battery," as he called it, worked was a matter of scientific debate. Only late in the 19th century did scientists identify the chemical processes involved in the fuel cell. Scientists including Ludwig Mond, Carl Langer, Charles R. Alder Wright, C. Thompson, Louis-Paul Cailletet, and Louis Joseph Colardeau continued research into the device, which they began calling a fuel cell. Most determined that, while fuel cells could produce energy, they were cost prohibitive for mass usage.

World War II, as it did so many other technologies, sped up research into fuel cells. Francis Thomas Bacon investigated using fuel cell stacks as energy producers in submarines to replace bulky storage batteries, but his work gained little traction. He continued periodic work on the cells in the 1950s; that work formed the basis of the NASA fuel cells.

Design

Any vehicle running on a hydrogen fuel cell will probably carry its own hydrogen. History buffs know that the German zeppelin *Hindenburg* was full of highly combustible hydrogen when it

exploded at Lakehurst, New Jersey, in 1937. (The United States had stopped selling Nazi Germany nonflammable helium by that time.) Proponents of hydrogen fuel cells say not to worry, though, because any hydrogen tanks in cars will be well-protected and well-grounded. Oxygen, obviously, is readily available. Cars already have grills and scoops to conduct air to internal combustion engines, and the basic components of fuel cell-driven cars will fit the spaces already designed into contemporary cars. But switching to fuel cell cars will not be as easy as swapping out parts.

Hydrogen Supply

Hydrogen is a component of 90 percent of the matter in the universe, yet it is not naturally occurring in a pure form. Before pure hydrogen can be used for any sort of power system, it must be separated from other elements. Traditionally, hydrogen has been taken from natural gas. High temperatures and high pressure separate hydrogen from carbons. The hydrogen is captured; the carbons become emissions, also known as greenhouse gases. Coal supplies most of the energy for the heating process, creating even more greenhouse gases.

At this writing, 95 percent of hydrogen in use is produced by this process. While the United States alone uses 10 million tons of hydrogen annually for industrial and scientific applications, experts say it will need 10 times that amount for hydrogen fuel cells to drive vehicles with anything like the ease of gasoline.

In short, the natural gas method involves using a fossil fuel to create a clean fuel from another fossil fuel, creating tons of carbon emissions in the process. Energy does result, but if eliminating pollution is the goal, the process is a loser. One method that could capture hydrogen from coal is to take the carbon dioxide resulting from the heating process and pump it underground, perhaps into exhausted oil or natural gas wells.

Another means of obtaining hydrogen is to strip it from water. That also requires intense heat, and most current water-heating systems use coal. Again, the pollution problem of energy goes unanswered. Nuclear power plants can conceivably create the heat but not until new generation plants come on line after 2020. They also pose other potential problems, such as the meltdown of the Fukushima nuclear plant after a tsunami hit Japan in 2011.



A researcher at the U.S. Department of Energy's Sandia National Laboratories in 2007 works with samples of a complex metal hydride, an advanced material for use in hydrogen storage systems that may be useful in hydrogen fuel cells for vehicles.

Storage and Distribution Problems

Hydrogen storage presents problems as well. Industry and science applications have long used liquefaction—turning hydrogen into a liquid by supercooling it. Liquid hydrogen tankers are a common sight on highways and railroads, and liquid hydrogen has powered spacecraft for years. But, again, the process is energy intensive and bulky, not conducive to the type of power needs that fuel cells in every car would demand.

Compressing hydrogen into storage tanks is easier to achieve, but tanks big enough to accommodate a trip of several hundred miles would be bigger than current gasoline tanks in cars. Tanks could also be made of “metal hydrides”—metal compounds that actually hold hydrogen and release it on demand—but they are inherently heavy and would add unnecessary weight to vehicles.

Traditional trucking of hydrogen—unless the semi tractor is itself alternatively powered—presents a fossil fuel catch-22: burning fossil fuels to

haul clean fuel created by using fossil fuels. The circular situation is somehow nonsensical.

Pipelines can be built for hydrogen transportation. Unlike oil, which will flow through a pipeline, hydrogen would have to be pressurized to move, and pipes would have to be reinforced to sustain the pressure. Thus, old pipelines could not be converted for this use; entirely new pipeline networks would have to be built.

Another possibility for hydrogen distribution is the isolation and capture of hydrogen at “hydrogen fueling stations.” As of 2013, this type of system was working at 36 stations in the United States. Having enough hydrogen stations around the country to fuel a hydrogen-powered transportation revolution is, of course, a major proposition. Car manufacturers estimate 11,000 hydrogen fueling stations coast-to-coast would be required to support what they call a “mature” consumer fleet of hydrogen fuel cell cars. Such an infrastructure would cost between \$20 billion and \$25 billion.

If all other obstacles were surmounted, experts say hydrogen fuel cells could propel cars for about 300 miles before needing a “fill-up.” Filling up would take much less time than a gasoline fill-up. That exceeds most electric car battery capacities.

However, one fuel cell is not sufficient. Fuel cells must be grouped in stacks to provide real power and range. Even then, fuel cell stacks seem durable only up to 75,000 miles before needing replacement. That is underwhelming given that the durability of most internal combustion engines allows them to go well over 200,000 miles.

Federal Planning

The many hurdles facing widespread use of hydrogen fuel cells would require government-scale planning, coordination, and incentives. The government has in the span of a decade both embraced hydrogen fuel cell planning and abandoned it.

During his two terms as president (2001–09), George W. Bush, a politician indebted to the oil business, posed as a champion of alternative energy. His budgets allocated \$18 billion for research, development, and promotion of alternative industries, \$3.5 billion of that in his last year in office.

Bush hailed hydrogen as a key to energy independence and a way to improve air quality. In 2003, he announced a widespread program to facilitate research and development specifically of hydrogen

fuel cells for cars. Bush also intended the research to prove the viability of fuel cells to provide energy for homes and businesses.

The Bush administration also presented the FreedomCAR initiative to develop efficient and safe techniques of hydrogen production and distribution. Bush's planners said that by partnering with the private sector, FreedomCAR would make fuel cell cars affordable, efficient, and readily available by 2020. The administration rolled out the program with a "Hydrogen Road Tour" featuring hydrogen cars made by General Motors, Daimler, Ford, Honda, Hyundai, Nissan, Toyota, Volkswagen, and BMW on a two-week tour of the United States. All the cars in the tour were experimental demonstration models.

Obama Alterations

In 2009, at the start of his first administration, President Barack Obama scuttled the Bush hydrogen initiative. Obama's energy secretary Steven Chu said the Bush program had not effectively solved any of hydrogen's major obstacles and that hydrogen would not be an effective replacement for gasoline by the Bush 2020 goal, or even a decade beyond that. While not ruling out any possibilities for hydrogen fuel cells, Obama preferred to allocate money to other energy projects that might prove successful sooner. Obama and Chu seemed more interested in promoting electric cars with onboard storage batteries.

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See Also: Alternative Fuels; FreedomCAR and Vehicle Technologies Program; Green Fuels; Green Transportation; Hydrogen Fuel.

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Hypersonic Flight

Hypersonic speed is the flight of an airship at a speed in excess of 5.5 times the speed of sound (Mach 5.5) in the atmosphere of the Earth. When a plane, bullet, rocket, or other object of force exceeds the sound barrier, it "breaks the sound barrier," creating a loud noise. As an object moves from transonic to supersonic, it experiences compression of the atmosphere so that at sea level it reaches the speed of sound at 768 miles per hour (1,235.52 km/h) and thereafter a penetration occurs that is visible on photographs. The effect makes the plane or other object look like it is surrounded by an audio speaker.

Since the German V-2 rockets of World War II, developments in aeronautical engineering have allowed spacecraft and airplanes to attain hypersonic speeds. During the 1960s the Air Force developed the X-plane series of experimental aircrafts. A number of the pilots flying X-planes were able to reach hypersonic speeds. The X-15 plane still holds the world's hypersonic speed record at 4,520 miles per hour (7,274 km/hour). This was Mach 6.7.

The space shuttle orbiter, the Apollo command module, and Buran jets also attained hypersonic speeds. The Russian Buran spacecraft was a Soviet-era orbital spacecraft. Soviet official statements claimed that Buran delivered cosmonauts and space material to an orbiting spacecraft. The Buran was an unmanned vehicle that was used only once before it was destroyed in a hangar accident in 2002.

Scramjets

Scramjets are supersonic combustion ramjets. They are a variant of an air-breathing jet engine or ramjet. They use high speeds to force air to compress as well as decelerate before it is used in combustion. Inside a ramjet, the air is compressed and slowed to subsonic velocities while at the same time it moves at a supersonic speed. In contrast, the scramjet uses airflow that is supersonic so that its utilization of the compressed air is more efficient. Scramjets can operate at supersonic speeds. They have achieved speeds of Mach 12 and Mach 24 for unmanned flights.

The design of scramjets is similar to all jets. Propulsion (forward thrust) is achieved by gases expelled from the engine. The engine is fed air through an intake opening that is compressed and decelerated; this air is combined with a gaseous fuel to burn the atmospheric oxygen that is in the air received by the inlet. The burn produces heat, which energizes the gases to produce thrust through a diverging nozzle.

Scramjet designs are different from turbojet or turbofan jet engines. The typical jet engine uses a rotating fan-like component to compress air and the burn then heats it; or, it may use multiple rotating turbine engines to compress air. These numerous moving parts are more complicated, add weight to the aircraft, and are liable to failure. Scramjets, in contrast, lack moving parts; however, they must be accelerated to high speeds in order to achieve optimal cruising speeds. It would essentially be a scramjet in a rocket plane.

Boeing Company is a manufacturer of aircraft for both civilian and military purposes. It built the unmanned experimental Boeing X-51A scramjet in a consortium with Pratt and Whitney Rocketdyne. The X-51 is also known as the X-51 WaveRider because it uses its supersonic shockwaves to add lift. In order to achieve its hypersonic speeds, it was launched at flight altitude from a Boeing B-52 Stratofortress over the Pacific Ocean on its first flight on May 26, 2010. It achieved speeds over Mach 5, or over a mile a second. The speed is sufficient for flight from New York to Los Angeles in less than 40 minutes.

Other X-51 flights were conducted in August 2010, in 2011, and in 2012. Anomalies developed in these flights that caused a loss of flight control. In one case a control fin malfunctioned, so hypersonic

speed was not even attempted. A remaining X-51 was not used. Pundits called the flight failure a disaster or a catastrophe, although the flight data was recovered for use in further developments.

Congressional funding for X-51 vehicles was cut after the plane's viability was challenged on technical grounds. The goal of the research is to ultimately produce and operate a plane that takes off from a runway, moves to the upper atmosphere, and then travels at Mach 6 before slowing to land at its destination runway. Use of the technology for military spy planes is an expected outcome of the research. On May 3, 2013, the final X-51 flight set a new record and raised the likelihood of new funding.

Hypersonic flights were conducted in the Australia Outback by its military. A successful hypersonic transport system would allow flights from Australia to Europe in trips lasting 90 minutes. Hypersonic flight is fraught with enormous engineering challenges from the heat and stress caused by rocketing through the atmosphere at such high speeds. Before a space liner can be built, new cooling technologies for shielding crew, passengers, and cargo from the intense heat will be needed. In addition, the strength of the materials used in the wings will need to withstand very high temperatures as well.

Bans

Efforts to ban supersonic flight over the United States have been ongoing since the early 1970s. On April 27, 1973 (14 CFR Parts 36 and 91), the Federal Aviation Agency (FAA) banned civilian supersonic flight over the United States because of the sonic booms. The ban was due to intense protests from people on the ground who experienced supersonic shock waves. In recent decades the National Aeronautics and Space Administration (NASA) and others have sought to improve flight engineering so that the FAA would be persuaded to allow overland supersonic flights.

The FAA supersonic ban was applied to the Aerospatiale-BAC Concorde supersonic transport (SST). The Concorde (*le Concorde* in French) was a commercially built and operated supersonic passenger jet by a joint French and British combination. It was eventually granted landing rights in the United States at subsonic levels. It made supersonic flights to the United States as well as to other destinations in half the time of regular carriers. It

was phased out following a crash in 2000 and the decline in air travel in 2003 that followed the terrorist attacks of September 11, 2001.

Despite the ban instituted in the United States, research on hypersonic flight is being conducted by other nations, including a combination of European nations. Engineers and scientists are using advances in computers and knowledge of fluid dynamics to find ways to reduce or eliminate sonic booms and their attendant noise and damaging effects. Commercially, hypersonic flight would be accomplished with less fuel, reduced crew size, reduced airport fees, and reduced passenger fatigue, and it would provide many other benefits, including rapid transport of medical patients and medical supplies.

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See Also: Air Travel; Aircraft Design; Aircraft Propulsion, New Technologies of; Airplanes; Noise Pollution and Airplanes; Space Travel, Commercial.

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ICT, Social Impacts of

Information and communication technologies (ICTs) are increasingly used in transport to make travel more efficient and cost-effective. However, such pervasive technologies do not come without an array of social impacts attached to them. Radical technological changes have occurred in the early 21st century, creating high expectations both for developed and developing countries. In the United Kingdom, an example of a developed country, mobile phone ownership has increased from 36 percent in 2000 to 91 percent in 2011, while the number of land lines has dropped from 93 percent in 2000 to 81 percent in 2011. Similarly, Internet penetration has risen from 25 percent in 2000 to 76 percent in 2011 (63.8 percent in the European Union) and the increase of mobile phone data transfer has increased 40 times between 2007 and 2010.

In contrast, the Internet penetration rate in Asia is 19.4 percent and only 6.8 percent in Africa. The entry level fixed broadband connection cost is on average \$28 per month in developed countries, but it averages \$190 per month in developing countries. Linking these facts with social media, 48 percent of adults in the United Kingdom have a social networking profile, while 57 percent of mobile phone Internet users there visit social networking sites through their mobile devices, making it the most popular activity.

Analogous is the situation in Italy, where almost every individual has two mobile phones, while smartphones are used by more than one out of three users in countries such as the United States, Sweden, Italy, and Germany. At the same time, almost half of mobile phone users in developed countries including the United States, the United Kingdom, Germany, Italy, and Australia use their phone to access the Internet.

More than 700,000 mobile applications existed at the beginning of 2013 in the two main smartphone apps stores, demonstrating an immense interest by users, businesses, and governmental organizations for ICTs and mobile Internet. Although there are households in developing countries where five people share the same phone device, highlighting the diverse needs in various contexts, it is universally acknowledged that accurate and timely information has become highly valuable.

There are a few sectors other than transportation where accurate and timely information is valued more. This is reflected not only in the ever-growing number of transportation related smartphone apps but also in the actual infrastructure installed in vehicles, railway stations, airports, car parks, or bus stops. The overall purpose of ICTs is to make passenger and goods transportation more enjoyable, safe, efficient, and cost-effective. Hence, certain areas require constant attention by academics, practitioners, and policy makers, such as the

increased role of social media, the altered levels of social interaction, personal safety, privacy, surveillance, inclusive access, and the digital divide.

Positive Impacts

Established trends such as tap cards for public transport (for example, TAP card in Los Angeles, Oyster card in London, and Octopus card in Hong Kong), e-tolls in motorways or urban areas (for example, in Stockholm or Singapore), and emerging trends, such as experiential marketing (which is already utilized by car manufacturers to provide a personalized test drive experience and eventually boost car sales), are becoming the norm in developed countries. The use of a common social media profile facilitates such services both for users and providers.

Another key benefit gained through the wide use of smartphones and improved infrastructure, such as 4G-LTE networks, is the opportunity for users and transportation authorities to receive real-time updates about congestion, transportation service overcrowding, accidents, and road work through ICT sensors. The widespread use of social media has facilitated this trend and opened up communication channels between users who may not have been acquainted with each other previously.

Personal safety improvement during journeys through location tracking by friends and relatives is another positive impact for vulnerable social groups, whereas augmented reality gadgets overlaying the real world with virtual or computer-generated images (for example, Google Glass) claim to provide a wealth of information to the user in interactive ways. If these claims are realized, this may be invaluable for car drivers, public transport users, pedestrians, or cyclists, because they will be offered real-time key information leaving their hands free, thus increasing their safety during journeys.

These developments have also aided more direct communication with local authorities, overcoming traditional bureaucratic and hierarchical structures to report bottlenecks or maintenance issues requiring immediate action. This has created a bottom-up approach which supports well-being while promoting resilient infrastructure, as it has been proven to be helpful in emergency situations, for example during natural disasters in the United States or social unrest in the Middle East.

The major implication of ICTs for transport, though, is the creation of new valuable data sets,

because individuals are constantly on the move, generating new data that can be used to inform policies, research, or business decisions. This has been highlighted by the World Economic Forum in its review of the overarching principles for using personal data, which need to be revised to ensure that ICTs protect the rights of individuals while at the same time unlocking socioeconomic value in a hyperconnected and hypermobile world. Personal travel data have high intrinsic value individually but also collectively, and this is exaggerated with the development of Big Data alongside ICTs, which generate vast amounts of easy-to-transfer data in industries such as public transport, railways, air transport, or logistics.

Contrasting the state-owned urban public transport operators in France (for example, RATP in Paris) with the private corporations providing similar services in the United Kingdom (for example, bus companies in Leeds), it is easily understood that transport authorities in conurbations benefit from the collection and use of such data in both cases. Therefore, it is crucial to manage the increasing volume of data in such a way as to ensure that any potential benefits will add value to all stakeholders in urban environments.

Open Data initiatives target such objectives, and there have already been some nascent but interesting applications aiming at near-live train departure updates or road maintenance reporting on the move. The latter is fueling the exponential growth of the volume of smartphone and Web applications related to urban transport, which spans across sectors as diverse as logistics, taxis, cycling, car sharing, car parking, car insurance, accident reduction through location tracking, personalized travel coaching, street maintenance, carbon emissions reduction and other “green” initiatives, as well as the promotion of healthier lifestyles through travel reward schemes.

Negative Impacts

On the other hand, ICTs for transport may introduce negative impacts to particular social groups. Disabled people (mentally or physically impaired people as defined by the World Health Organization) face such impacts because many of the new services, infrastructure, or smartphone apps have not made any specific provisions for them (or they only provide a restricted version for their needs),

leaving them disadvantaged. The elderly or those who are not familiar with new technology form another disadvantaged group. These so-called technology illiterate may also be affected by the cost of new infrastructure or devices, which creates social inequalities linked to their income or home location.

Further, due to the increased time people have been observed spending using smart devices, a decrease has been reported concomitantly in time spent on actual interaction with family, friends, and colleagues. In addition, the fact that workers may be required to work while on the move because of the ubiquitous nature of ICTs creates a further strain in the attempt to retain a work-life balance.

This introduces the important topic of privacy and surveillance, which has been under-researched in this domain despite being already a concern for bus, coach, and truck drivers.

An associated contemporary policy debate within the European Union (EU) is about the “right to be forgotten” (that is, the option to completely delete one’s on-line data). No political consensus exists about this issue, yet, as it is opposed by U.S. corporations using individual data. Opponents of the right to be forgotten in the United Kingdom claim that the British economy may lose \$156.5 million to \$563.3 million (100 million to 360 million pounds) annually in lost revenue, whereas EU officials advocate that there will be additional annual revenues of \$3 billion (2.3 billion euros) as a result of increased consumer trust in online services.

While this debate remains, it is a fact that increased mobility has created a need for increased

identity construction and control. For that reason, data collection, standardization, storage, and sharing practices, particularly regarding cross-border transportation services, constitute priorities of authorities worldwide.

Nevertheless, a primary international concern with implications for transportation service quality is the remaining digital divide both socially and spatially. Table 1 examines this topic using selected rankings from the Economist Intelligence Unit and the Global Information Technology Report based on a mixture of factors, such as connectivity, human capital, sophistication of use of ICT, geographical dispersion, and legal and political considerations. These rankings show a clear distinction between levels of readiness between developed, emerging, and developing countries. Another important point is that, despite a decade of progress, several of the selected countries have not seriously advanced their global position, suggesting that a relative digital divide persists. The reasons for the digital divide are well documented in the academic literature and echo that of other socioeconomic divides.

Yet, expectations for emerging wireless and mobile technologies are high globally. Some observers conclude that several developing countries, having bypassed landline phones, will bypass the personal computer and leap-frog straight to mobile Internet. This is founded on the premise that mobile technology pledges improved opportunities for enhanced interconnectedness and transportation services to several social groups. Because of

Table 1 Global information technology report rankings

	Sweden	U.S.	India	Colombia	China	Haiti	Nigeria
2013 Out of 144 countries	3	9	68	66	58	141	113
2008–09 Out of 134 countries	2	3	54	64	46	n/a	92
2001–02 Out of 75 countries	4	1	54	57	64	n/a	75

Source: World Economic Forum, 2013 and 2009 and Geoffrey Kirkman et al. *The Global Information Technology Report 2001–2002: Readiness for the Networked World*. New York: Oxford University Press, 2002.

this, R&D has not focused on population segments having joined the digital revolution at a slower pace, who have low-quality transportation and ICT infrastructure available.

Other social impacts to address are unintended consequences of ICTs for transport, energy use inequalities, and technological optimism bias, because it has been documented that it is not technology per se that matters the most but the use of technology for the wider social benefit.

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See Also: Emerging Technologies; Information Technologies and Transportation; Intelligent Transportation Systems; Telematics.

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Impaired Driving

Impaired driving describes the operation of any motor vehicle under the influence of alcohol or other intoxicating substances. It is also called driving under the influence (DUI), driving while intoxicated (DWI), operating while impaired (OWI), or operating a vehicle under the influence (OVI). Impaired driving in the 21st century can also include driving while talking on a cell phone, reading, or engaging in any other activity that affects concentration, reflexes, and handling of the steering wheel or other operation features while the vehicle is in motion. The U.S. federal government identifies this phenomenon as "distracted driving."

Impaired or distracted driving causes people to lose control over their vehicles and dramatically increases the risk of fatal accidents. Not only the driver but also passengers, people in other vehicles, pedestrians, and animals are all at risk for injury or death if an impaired driver is behind the wheel. The potential number of lives lost dramatically increases when someone under the influence of drugs, alcohol, or distracting technologies operates public transit. While most nations have laws that criminalize driving while under the influence of alcohol or other substances, governments are just starting to address distracted driving. Such laws may also apply to boating, flying an airplane, or operating farm machinery or horse-drawn carriages.

Impaired Driving

Nearly one-third of car crashes involve alcohol-impaired drivers; these impaired drivers cause roughly one-third of all traffic-related deaths.

Over half of the child passengers aged 14 years and younger who died in alcohol-related crashes were riding in a vehicle with an alcohol-impaired driver. Although over 1.4 million drivers were arrested for driving under the influence of alcohol or narcotics, those arrests make up only 1 percent of the 112 million self-reported episodes of alcohol-impaired driving among adults in the United States each year. Drugs such as marijuana and cocaine are involved in approximately 18 percent of motor vehicle driver deaths; these drugs are often found in the driver's system in addition to alcohol.

Driving while under the influence of alcohol (DUI) is considered a criminal offense in most nations. Due to strict laws and proactive education about driving under the influence, the number of DUI arrests in the United States has declined significantly. In the United States, traffic officers who have reason to believe that a driver is under the influence will ask him or her to perform certain tests, such as walking in a straight line and placing the tip of their finger on their nose. This is called a field sobriety test, developed by the National Highway Transportation Safety Administration (NHTSA). If the driver cannot pass this test, the traffic officer will test the driver's blood alcohol content (BAC) to determine whether alcohol is present in the blood and whether it is sufficient to impair driving. Younger car drivers are more at risk of being involved in a crash regardless of their BAC level, while older motorcyclists are more at risk. Penalties for DUI differ from state to state and increase in severity depending on whether the DUI incident led to fatalities. Most importantly, those drivers who face DUI penalties are often required to attend a prescribed number of counseling sessions or to join a 12-step program to address any substance abuse problems that they may have.

Distracted Driving

Distracted driving is a relatively recent phenomenon. Text messaging, in particular, is the most dangerous distraction as it requires visual, manual, and cognitive attention from the driver. Roughly 20 percent of crashes resulting in injuries are caused by distracted drivers. Using a cell phone while driving reduces the amount of brain activity associated with driving by nearly 40 percent; an Australian study showed that drivers who use handheld devices are four times more likely to get into injury-causing crashes.

History of Driving Under the Influence

Human beings have consumed alcoholic beverages and behavior-altering substances for at least 6,000 years. An impaired pedestrian or horseback rider, however, presents less of a safety risk than an impaired person behind the wheel of a motor vehicle. As cities developed and motor vehicles began to share the road with horse-drawn vehicles and pedestrians, impaired drivers presented a great danger to public safety.

The first law in the United States to prohibit drinking while driving was set in 1843 by the New York Central Railroad to prohibit drinking by employees while on duty. In 1897, the first DUI arrest took place in London. Taxi driver George Smith slammed his cab into a building while under the influence of alcohol. Smith pled guilty to the charges and was fined 25 shillings. In the United States, in 1910, New York was the first state to implement laws against operating motor vehicles while under the influence of alcohol. California and other states soon followed. While these early DUI laws prohibited driving while intoxicated, they did not provide a definition of intoxication, or what level of inebriation qualified as drunk driving. Police officers did not know how to assess a driver for drunkenness, nor did they have a convenient way to measure it.

As early as 1874, scientists could detect alcohol through someone's breath, but no one had put this discovery to practical use. Prior to the breath tests, police measured alcohol content through blood samples. Police had to transport the driver to special locations, contact physicians in the middle of the night to perform this procedure, and then safely store and transport the blood to a laboratory, which delayed results being delivered to the investigator and sometimes resulted in suspects getting away. In 1936, American biochemist and toxicologist Rolla Neil Harger from Indiana University developed a practical, portable machine to test human breath alcohol content. He called his invention the "Drunkometer." To measure a subject's blood alcohol content using the Drunkometer, Professor Harger had them blow into a balloon. The subject's breath sample was then pumped through acidified potassium permanganate, which would change color if alcohol was present in the sample. The more alcohol in the sample, the greater would be the change in color. Using a calibrated color chart,

it was possible to determine the alcohol in a breath sample with reasonable accuracy and from there to calculate blood alcohol levels. In 1953, former police captain and codeveloper of the Drunkometer Robert Borkenstein invented the Breathalyzer. This machine was an improvement over the Drunkometer in its compact size, ease of use, and reliability. The Breathalyzer is still used by police to measure blood alcohol levels.

In spite of having an instrument to measure blood alcohol content, police did not receive consistent training to determine whether a driver in custody could be impaired. As a result, many people stopped by the police for erratic driving either were cited for not following traffic safety laws or simply let go. In 1938, the National Safety Council established the Committee on Tests for Intoxication to gather information from select police departments on how they identify impaired drivers. In 1977, with the support of the NHTSA, the Southern California Research Institute evaluated the physical coordination tests used at the time to determine the inebriation of a suspect. This was the first significant assessment of the tests under real law enforcement conditions. Two hundred thirty-eight volunteers were subjected to a series of tests most frequently used in the field; researchers standardized objective clues and scoring criteria for the tests. The NHTSA standardized field sobriety testing; police officers across the United States now receive training to administer three tests—the one-leg stand, the walk and turn, and the horizontal gaze nystagmus—to determine inebriation according to consistent standards prior to administering a Breathalyzer test.

Despite advances in blood alcohol testing, people did not receive much education about drunk driving until the late 1970s. Because police officers finally had the tools to identify inebriated drivers and measure their blood alcohol content, lawmakers could write stricter DUI laws. In 1980, a California woman named Candy Lightner founded Mothers Against Drunk Driving (MADD) after her 13-year-old daughter Cari was killed by a drunk driver while walking home from a school carnival. The driver had three previous DUI convictions and was out on bail from a hit-and-run arrest two days before Cari's death. Lightner formed MADD to change attitudes about drunk driving and to push for legislation that increased penalties for driving under the influence of alcohol or drugs. MADD

also helped raise the minimum drinking age to 21 in most states.

Today, the legal drinking age is 21 in all 50 states. Convicted drunk drivers face a wide variety of penalties, ranging from jail time, fines, restriction or loss of their driving privileges, and increased car insurance rates. Only the state of New Jersey still considers a DUI without injury or death as a simple traffic violation. Each state has designated a blood or breath alcohol level to confirm a driver's state of intoxication and serve as a threshold for a criminal offense. Six states require physicians to report patients who drive while impaired, and another 25 states allow physicians to violate doctor-patient confidentiality to report impaired drivers. Some drunk drivers are ordered to have ignition interlock devices installed in their vehicles. These devices require a driver to breathe into a sensor attached to the dashboard; the car will not start if the driver's blood alcohol concentration is above a certain limit.

Special DUI courts provide substance abuse intervention for repeat offenders who plead guilty to driving while intoxicated. The courts enroll these offenders into a program that requires them to abstain from alcohol and wear a device to monitor and record any level of alcohol detected in their bodies. Some states, such as Ohio and Minnesota, issue special license plates to DUI offenders who are granted limited driving privileges for work or school until a court can reinstate full driving privileges. These plates are a different color from the standard-issue plates, start with the same letter, and do not have the same number of characters as regular plates.

Federal Aviation Regulation 91.17 prohibits pilots from flying aircraft with a BAC of 0.04 percent or more, or within eight hours of consuming alcohol, or while under the influence of any drug. This same prohibition applies to all crew members on duty. Commercial pilots charged with flying under the influence are terminated or may resign voluntarily; flying under the influence can result in loss of pilot certification or criminal prosecution under federal or state law.

Distracted Driving Legislation

To date, the most serious accident caused by distracted driving took place in September 2008. A Metrolink rail employee using a cell phone killed 25 people in a train crash in Chatsworth, California. This tragic accident caused the Federal



With the help of a computer-assisted DUI simulator, a college student experiences what it would feel like to attempt to drive under the influence. Such simulators are used in educational programs to help prevent impaired driving. Almost one-third of all car crashes involve alcohol-impaired drivers; these impaired drivers also cause as many as one-third of all traffic-related fatalities. In the United States, more than 1.4 million drivers are arrested for driving under the influence of alcohol or narcotics every year.

Railroad Administration to ban all rail employees from using cell phones or other electronic handheld devices on the job.

The U.S. Department of Transportation initiated a regulatory campaign against distracted driving. The campaign has involved prohibiting handheld device usage, including text messaging, while operating automobiles, trains, planes, or commercial vehicles. This campaign began in 2009, when President Barack Obama signed an executive order directing federal employees not to engage in text messaging while driving government-owned or privately owned vehicles while on official government business. The order also advised federal contractors and others doing business with the government to adopt and enforce their own policies outlawing texting while driving.

In September 2010, the Federal Motor Carrier Safety Administration (FMCSA) banned commercial truck and bus drivers from texting while

driving. In November 2011, it banned all handheld device usage by commercial drivers. In February 2011, the Pipeline and Hazardous Materials Safety Administration (PHMSA) banned texting on electronic devices by drivers operating motor vehicles containing hazardous substances.

In 2009 a Northwest Airlines flight crew overshot their destination by 150 miles due to distraction from a laptop. In response, the Federal Aviation Administration (FAA) advised all air carriers to create and enforce policies that limit distractions in the cockpit and keep pilots focused on the skies.

In the United States, all of the 50 states have at least one law criminalizing handheld device usage while driving, texting while driving, or both. Unfortunately, current laws do not always address all drivers in all situations. Some laws only criminalize device usage or texting while driving for a particular segment of drivers, such as teenagers or bus drivers. Other laws criminalize distracted driving in certain

locations, such as around schools or in areas with heavy pedestrian traffic. Enforcement of these laws is inconsistent, as a driver stopped by the police for erratic driving who is not captured on video can easily hide the device.

DUI Investigation and Arrest

Law enforcement officers come in contact with impaired drivers in multiple ways. The officer might respond to the scene of a car accident, notice that the driver is impaired, and begin an investigation. Sometimes police receive a report from a concerned citizen who describes a car driving erratically, locate the driver, and pull them over. An officer on patrol might observe suspicious driving or a series of traffic infractions committed by the same driver. Finally, a police officer might stop a vehicle for a lesser offense, notice signs of intoxication, and begin an investigation.

Sobriety checkpoints involve traffic police or highway patrol stopping either every vehicle or every *n*th vehicle on a public roadway to investigate the possibility that drivers may be too impaired to drive. These checkpoints are often set up late at night, the very early morning hours, weekends, or during holidays or events that may involve heavy drinking. Checkpoints are often situated near the exit points at public events to prevent the simultaneous release of drunk drivers onto the road. If the law allows, the police can give a breath test to all drivers. If the officer cannot perform a quick test but has reason to suspect intoxication, the officer may require that the driver exit the vehicle and take a sobriety test to prove mental and balance skills. If the driver fails that test, the officer can then administer a Breathalyzer test.

Sobriety checkpoints have come into conflict with the Fourth Amendment of the U.S. Constitution, as some believe they violate the right of persons to be secure against unreasonable searches. In 1990, in *Michigan Department of State Police v. Sitz*, the U.S. Supreme Court found sobriety checkpoints to be constitutional; Chief Justice William Rehnquist argued that the state interest in reducing drunk driving outweighed individual privacy. The NHTSA issued a report that provided recommended checkpoint procedures in line with federal and state legal decisions to prevent violations of constitutional and civil rights. Though the Centers for Disease Control and Prevention and the independent organization

Public Health Law Research both issued reports proving that sobriety checkpoints reduce the number of alcohol-related driving fatalities by at least 20 percent, most states employ the checkpoints sparingly. Ten states do not allow sobriety checkpoints at all under their state constitutions.

The NHTSA has published a list of 19 DUI symptoms to train officers to identify impaired drivers. Each symptom includes a percentage figure that indicates the statistical chances that a driver is over the legal blood alcohol content limit. Symptoms are listed from most likely to indicate intoxication (straddling center or lane marker) to least likely (headlights off). If the officer observes one or more of these symptoms to build reasonable suspicion to legally justify investigation and detention, he/she will stop the car, approach the driver's window, and ask some questions. During this phase the officer will note whether he/she detects alcohol on the driver's breath, slurred speech, watery or bloodshot eyes, flushed face, or other physical indications of intoxication.

If the officer has reasonable suspicion to legally justify further detention and investigation, he/she will ask the driver to step out of the vehicle for a sobriety test. The three validated NHTSA tests are (1) the horizontal gaze nystagmus test, which involves following an object such as a pen with the eyes to determine eye movement reaction; (2) the walk-and-turn, designed to measure a person's ability to follow directions and remember a series of steps while dividing attention between physical and mental tasks; and (3) the one-leg stand. These tests indicate a probability that a driver is at or above the legal blood alcohol limit.

If the officer has sufficient probable cause that the suspect has been driving while intoxicated, the suspect will be arrested, handcuffed, and transported to the police station. At the station, the police will test the driver's blood, breath, or urine for alcohol or drug content. If the tests show that the driver's blood alcohol content is not at or above the legal limit of 0.08 percent, the driver is released without any charges. If not, the driver will either be kept in a "drunk tank" until officers believe he or she is sober enough to be released on bail, or they will be subject to appear in court at a future date.

Driving Under the Influence of Drugs

Driving under the influence of any drug can impair one's motor skills, reaction time, and judgment.

Many over-the-counter or prescription medications can make a driver sleepy and cause them to lose control of the vehicle, thus causing an accident. According to the NHTSA, more than 16 percent of weekend, nighttime drivers tested positive for over-the-counter, prescription, or illegal drugs. Nearly 20 percent of fatally injured drivers tested positive for at least one drug. In spite of the increase in “drugged driving” arrests, specific drugged driving legislation has lagged behind alcohol-related driving legislation.

Few state laws identify “drugged driving” as a condition distinct from DUI; if they do note the condition, they simply identify it as “driving when a drug renders the driver incapable of driving safely” or “causes the driver to be impaired. As a wide variety of drugs exist on the market, whether legal or illegal, law enforcement and other researchers have not come to consensus on which drugs to study in order to determine drug levels that would cause impairment. Also, some drugs remain in the body for days or weeks after initial ingestion.

Forty-four states have established Drug Evaluation and Classification Programs, designed to train police officers as drug recognition experts (DREs). Similar to sobriety field test training, officers learn to detect characteristics in a person’s behavior and appearance that may be associated with drug intoxication. If the officer suspects drug intoxication, he/she will bring the driver to the police station where a blood or urine sample will be taken and submitted to a medical laboratory for confirmation. Seventeen states have passed “per se” laws, which state that it is illegal to operate a motor vehicle if there is any detectable level of a prohibited drug (such as marijuana or cocaine) in the driver’s blood.

The DRE protocol is a 12-step process to establish through a series of tests whether an impaired driver was driving under the influence of drugs. This process is more time intensive than the sobriety field test and the Breathalyzer, which may be a reason why most states do not have separate legislation for drugged driving. The first four steps of the process include assessments from the sobriety field test, as well as taking the driver’s pulse. The DRE will ask a series of standard questions in relation to the driver’s health and recent consumption of food, alcohol, and drugs, including prescribed medications. The DRE will observe the subject’s attitude, coordination, speech, breath, and face. The

DRE will also determine whether or not the driver’s pupils are the same size. If the DRE believes that the driver may be suffering from a significant medical condition, the DRE will seek medical assistance for the driver immediately. If the DRE believes that the driver’s condition is drug related, he/she will continue the evaluation. Further steps in the investigation include an eye examination, vital signs and second pulse, examination for muscle tone, a check for injection sites, and a third pulse. The DRE will then read the driver their Miranda rights and ask the driver more targeted questions about their drug use. At that point, the DRE will form an opinion as to whether the driver is impaired. If the driver is impaired, the DRE will request a urine, blood, or saliva test from the driver.

DUI Outside the United States

The illegal BAC for most of the United States is higher than all other first world nations, as identified in a report published by the NHTSA. At the same time, the minimum purchase age for alcohol is older in the United States than in most other first world nations, while the minimum driver license age for most countries is older than the minimum legal purchase age for alcohol. Penalties for DUI in other countries are often much stricter than in the United States; they range from heavy fines, revoking driving privileges, prison, or house arrest under electronic surveillance. Some countries require proof of successful alcohol or substance abuse counseling prior to returning driving privileges. Police in other countries have more authority to stop and test drivers for BAC at will.

Prevention and Interventions

Reducing the frequency of drunk driving in the United States requires education and community-based approaches for treatment. The National Institute for Alcohol Abuse and Alcoholism states that environmental interventions are most helpful to eliminate drinking and driving altogether. As young drivers are most likely to get into car accidents, the most successful solution to reduce impaired driving and DUI fatalities was raising the minimum drinking age to 21 years of age. This federal law, in conjunction with MADD, has led driver education programs and high schools across the United States to include information about substance abuse, impaired driving, and its legal consequences in curricula. Law

enforcement officers visit schools and talk to students about DUI-related accidents they have witnessed, sometimes even bringing in the windshield or dented car door for added effect. If this cannot be arranged, students watch videos that help them reach the same conclusion—that DUI is dangerous and not worth the risk.

MADD inspired the creation of a student chapter—Students Against Drunk Driving, or SADD—in 1981. SADD has become the leading peer-to-peer youth education and prevention organization, with thousands of chapters in middle schools, high schools, and colleges. It endorses a firm “No Use” message related to alcohol and other drugs and provides helpful advice to students who do decide to attend parties where alcohol is served. SADD has taught high school and college students about “designated drivers,” how to collect car keys from everyone at a party if alcohol is served, and encourages people who had too much to drink to spend the night at a friend’s house if necessary before getting back on the road.

In spite of the lack of “drugged driving” legislation, aggressive substance abuse education has taken place in the United States since the mid-20th century. Although use of illegal drugs among youth has decreased in the United States, more young people are abusing psychiatric drugs and over-the-counter medications, which also have an impact on their ability to drive safely. Recently, SADD changed its name from Students Against Drunk Driving to Students Against Destructive Decisions to include drug use and other self-destructive behaviors as well as risky impaired driving.

City, county, and state employment application procedures often include requesting information from the Sheriff’s Department and the Department of Motor Vehicles about applicant driving history and criminal background, if any. DUI offenses of any kind may limit a job seeker’s employment opportunities, especially if they are applying for positions in education, health care, or other human services professions where they may be required to transport people or operate vehicles or heavy equipment while on the job. DUI is still perceived as a character flaw in many parts of the United States, as well as a criminal offense. Knowledge that DUI offenses stay on one’s record and can affect one’s job opportunities may make people think twice about driving under the influence.

Americans work longer hours than people in other countries and are often expected to multitask while on and off duty. As they balance work, education, and child care, they frequently drive distracted and medicated. Perhaps the most helpful intervention that government can provide for drivers to reduce DUI arrests is to provide more child support for single parents and low-income families.

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See Also: Automobile Accidents and Prevention; Distracted Driving; Federal Aviation Administration; Federal Motor Carrier Safety Administration; Motorcycle Safety; National Highway Traffic Safety Administration; Pipeline and Hazardous Materials Safety Administration; Transit Safety.

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Incident Detection Systems, Airplane

The rise in the frequency and seriousness of incidents and accidents in modern aviation history

has heightened awareness of aviation safety, spurring the development of incident detection systems. Among the most serious incidents that threaten aircraft safety are collisions with terrain or other aircraft, runway incursions, weather hazards, and aircraft fires. Incident detection systems have advanced with technological developments, accident investigation and safety recommendations, improved flight crew and air traffic control (ATC) training, and new government and industry requirements.

The International Civil Aviation Organization (ICAO) and U.S. Federal Aviation Administration (FAA) classify occasions associated with aircraft operation that affect or threaten operational safety based on seriousness. An aviation accident is defined as an occasion associated with aircraft operation that results in fatal or serious injury or serious aircraft damage or structural failure, or an inaccessible or lost aircraft. An aviation incident is defined as an occasion associated with aircraft operation that affects or threatens operational safety without meeting the qualifications for classification as an accident.

Fire and Weather

Aircraft fires pose a significant danger due to multiple potential fire sources, the confined space of an aircraft, and the difficulty of escape, especially if an aircraft is airborne. Automatic heat- and smoke-sensing equipment enable the early detection of aircraft fires, allowing flight crews or automatic equipment to initiate countermeasures before a fire becomes uncontrollable. Response can be manually initiated by the flight crew or automatically initiated by computer-controlled equipment, based on the alert location.

Heat-sensing fire alert systems are commonly used in engines and auxiliary power units (APUs), high temperature bleed air leaks, and landing gear bays, whereas smoke-sensing systems are commonly used in toilet compartments and avionics bays. Cargo holds utilize both types of systems. Sensing equipment alerts sound either locally at the source where heat or smoke is detected or at a central location. Automatic sensing equipment does not detect fumes, leaving their manual detection and alert primarily to the flight crew.

Adverse meteorological conditions are a common and significant safety threat to arriving, departing,

or in-flight aircraft. Two of the most dangerous meteorological threats are icing and wind shear. Ice detection and protection systems protect both the aircraft surfaces, such as the wings, and the aircraft engine. Deicing systems detect and remove ice that has already accumulated. Anti-icing systems are designed to prevent ice from forming but are also commonly used as deicing systems as well. Common systems include thermal deicing and anti-icing systems and pneumatic deice boots.

Wind shear generally refers to the presence of rapid changes in prevailing wind currents. The meteorological phenomenon known as a microburst has been known to produce strong wind shear and has been targeted as the cause in several well-known aviation accidents. Wind shear can cause aircraft to suddenly accelerate airspeed and ascend. Pilot awareness of wind shear is critical to avoid the manual reduction of engine power, which will result in a sudden deceleration of airspeed and loss of altitude as the aircraft emerges from the wind shear.

Most aircraft rely on onboard predictive wind shear sensor systems based on microwave radar, Doppler LIDAR radar, or infrared. Many airports are also equipped with ground-based systems such as the Low-Level Wind-Shear Alert System or the Terminal Doppler Weather Radar system. Radar weather detection systems can also alert flight crews or air traffic controllers to other potential incidents arising from the presence of turbulence, storms, or lightning.

Collision Avoidance

Collision avoidance has become a primary aviation safety issue due to air traffic and airport congestion, as well as predicted air travel growth. Future airspace and airport capacity increase through programs such as the FAA's NextGen, which will place aircraft in greater proximity, will only increase the future need for incident detection systems that identify potential ground and in-air collision incursions.

Runway incursions are common potential sources of ground-based collisions. The ICAO defines a runway incursion as any incident involving the incorrect presence of an aircraft, vehicle, or person on a runway (the designated surface for aircraft takeoff and landing). The FAA uses a similar definition with the exception that the term *surface incident* is used if there is no potential for collision



Proteus, a tandem-wing research plane, has been used by the National Aeronautics and Space Administration for tests of collision-avoidance flight systems for unmanned aerial vehicles using a radar unit installed underneath the aircraft's nose cone.

with an aircraft, such as if the runway where the incursion takes place is empty.

There are numerous causes for runway incursions, broadly categorized as those originating from pilot error, air traffic control error, or other conditions. Examples include pilot noncompliance with ATC clearance, the issuance of and compliance with invalid ATC clearance, or ground vehicle runway incursion without ATC clearance. Contributing factors can include poor weather or visibility conditions, flight crew unfamiliarity with the airport, airport design and function, language issues, heavy workloads, and other distractions.

Alerting air traffic controllers and flight crews to potential or actual runway incursions is vital, as aircraft on runways are often traveling at high rates of speed, increasing potential for damages, injury, and loss of life. Runway incursions have been responsible for some of the world's deadliest aviation accidents, such as that which occurred at the Tenerife airport in 1977. Computer-based systems in use

to alert to potential or actual runway incursions include traffic alert and collision avoidance systems (TCAS), runway awareness and advisory systems, enhanced vision systems, the FAA's Airport Surface Detection Equipment Model X (ASDE-X), and Northrop Grumman's Airport Movement Area Safety System (AMASS).

Aircraft-based, in-air collision incident detection systems were designed to work independently of those ground-based systems employed by ATC as a safety backup. Ground proximity warning systems and enhanced ground proximity warning systems, also sometimes known as terrain awareness and warning systems, prevent collisions with terrain. TCAS are the most common detection systems used in private and commercial aircraft to avoid in-air collisions. Many military aircraft are also equipped with TCAS or modified TCAS to enhance safety.

TCAS systems provide flight crews with traffic and resolution advisories. A traffic advisory alerts the flight crew to nearby aircraft and their locations to allow for visual acquisition. Resolution advisories provide the flight crew with recommended escape maneuvers. TCAS I systems provide only traffic advisories, and newer TCAS II systems provide both types of advisories.

TCAS systems utilize surveillance, collision avoidance system (CAS) logic, and pilot displays. TCAS analyzes aircraft transponder information received from other aircraft in proximity to determine whether a collision is possible and whether evasive maneuvers are necessary. Traffic and resolution advisory displays visually and audibly show the flight crew proximate aircraft, threat level, and necessary maneuvers. Common problems with TCAS include the issuance of so-called nuisance advisories in certain situations where there is no danger of collision or need for escape maneuvers.

Newer developments in collision avoidance systems include Automatic Dependent Surveillance-Broadcast (ADS-B) technology, TCAS-ADS-B hybrid systems, and Airborne Collision Avoidance System (ACAS-X). The FAA began development of ADS-B in the 1990s. The ADS-B system is based on aircraft self-reporting of necessary flight data, whereas hybrid systems allow TCAS to utilize ADS-B gathered data. ACAS-X was under development by the FAA as of 2013, with many European countries also expressing interest. This new system

represents a complete redesign rather than an overhaul of TCAS.

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See Also: Air Traffic Control; Air Traffic Controller Training; Airplane Disasters; Airplane Navigation Systems; Collision Avoidance Systems, Airplanes; Next-Generation Airports, Federal.

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Incident Detection Systems, Automobile

Incident detection systems include a variety of automatic incident detection (AID) equipment intended to reduce risk on busy roads and highways. The idea is to install a substantial network of video cameras to provide continual and complete coverage of the movement of traffic and to link this to a computerized system that will identify any incidents—collisions or breakdowns, for example—that would compromise safety and, consequently, automatically trigger a traffic-calming signal in the affected area. The same system would also be used to determine when the incident has been resolved and when normal driving conditions can be resumed. The ability of traffic authorities to deploy this kind of technology has only been developed in recent years and problems persist, not least of which is cost.

One of the better-known systems is MIDAS—the Motorway Incident Detection and Automatic Signaling—which was introduced on the M25 circular motorway around in the United Kingdom in 1997. Previous versions of this system had been trialed on the M1 and M4 routes, which are also extensive multilane highways along which cars can move at up to 70 miles per hour (mph; 113 kmh) and along which personal automobiles and large trucks share space. The volume of traffic and the amount of territory involved mean that the likelihood of the police or emergency services being able to respond in time would be slim, which means there is a need for technology. This approach enables the state to retain control of road traffic management, increasing productivity of the personnel employed and incorporating elements from the private sector that might not otherwise be available.

The Technological Challenge

That incident detection systems have only recently been introduced and are still under development indicates the complexity of the technology involved. There are various elements that must be balanced with each other and, as is often the case, it is in the connections between two or more subsystems that most difficulty can arise. Governance issues are usually quite straightforward to manage, with the road system involved being under the jurisdiction of a specific national or regional level authority (as privatization of roads is not widespread) and the service provider generally being a private-sector concern under contract for a specific project and its upkeep. However, there is a need for a close relationship between the service provider and the authority because of the importance of the work, which concerns not only safety but the legal use of the roads. Sumitomo's AID is part of a suite of services, including a license plate recognition system and a traffic flow control system. It can monitor both fast and stopped vehicles, those traveling in the wrong direction, those frequently changing lanes, and excessive congestion. The network must be established and maintained, the video captured at a central location, processed so that only relevant incidents are brought to a higher level of attention, the correct response elicited and then implemented. At the same time, there is a need to integrate the results with those of neighboring systems, if these are in operation. It is also necessary

to develop a database of video footage in a format permitting additional analysis such that awareness of the need to take action and the type of action to take will be constantly refined and improved. To some extent, data gathered from one location may be used in analyzing conditions in other locations, although there are issues relating to the ownership of data, its means of analysis, and transferability to other locations.

In addition to the hardware and connectivity issues, there is also the conceptual basis of the software systems to incorporate into the overall network. Although it is often imagined that traffic resembles a liquid, in that it could be made to flow efficiently if only the correct system of pipes and connections could be found, in fact, traffic should be better thought of as a gas, which expands to fill whatever space is available and attempts to escape through any defects in the system. To tackle this complexity, fuzzy sets and neural networks are among the approaches employed, while the development of new algorithms aimed at understanding and predicting events has benefited considerably from the advent of low-cost and massive computational power. As they have been successively introduced, these are systems that would not have been possible even a few years earlier.

Spread of Automated Highway Systems

The forerunners of incident detection systems can be found in the partnerships between General Motors and the government from the time of the 1939–40 World's Fair. The concept initially was one of personal freedom for the driver, who could relax with his family (as driving was generally a gender-distinct activity) while the car drove itself. In conjunction with the Radio Corporation of America (RCA), General Motors was able to demonstrate self-driven cars going around racetracks. These early initiatives were developed into joint research programs featuring the Bureau of Public Roads and later the Federal Highway Administration (FHWA). However, national-level initiatives were ceased in 1981 as the result of a new ideology seizing control of government, and the focus on new technology switched to Europe and Japan, where serious attempts were not begun until the 1960s but which then overtook American efforts. European activities in this regard were primarily international in nature, owing to the relative and growing closeness

in cooperation between some western European countries that shared important road systems and because of the desire to obtain economies of scope and scale in research. In Japan, the period of rapid economic development was administered and overseen by the Ministry of International Trade and Industry, which developed close relationships with large corporations that were encouraged to enact state-level development priorities. Subsequently, new research partnerships in the United States have led to return of attention to that country as one of the leaders in incident detection system development and deployment.

The Panopticon

The French philosopher Michel Foucault described a prison system in which cameras watched all the convicts all the time. Once the convicts believe that everything they do will be seen and punishment will meet any transgression, they will obey the law at all times, at which point there will be no need for anyone to be monitoring the cameras or for the cameras to be working at all. This link between technology and social control is one that troubles many people on the basis of civil liberties. Although the purpose of the system is safety and few people would argue that there is not a need to reduce risks in a very dangerous environment, it has become evident that data obtained can be used in a wide range of applications and, since storage of data has become very cheap, could be maintained on a more or less permanent basis. The use of automated data mining techniques could be used not just to identify when crimes or misdemeanors have been committed but also could monitor the movements of individuals and use this in ways that many people feel contravene the privacy that they believe they have a right to enjoy.

A related issue is the right that some people feel they have to drive their automobiles in the way they choose, within the context of the existing laws and common sense. This is particularly true in the case of individualistic societies such as the United States, where driving an automobile at all can be construed as an act of personal freedom. There is little doubt that traffic planners would generally prefer automated systems to take preference for the same reason that aircraft are safer to fly when they are under the control of the autopilot rather than the human pilot. If all automobiles could be

controlled, then more could be safely arranged in proximity to each other at an even pace, resulting in quicker and safer journeys, more efficient use of resources, and reduced costs of traffic management and automobile repair and maintenance. These measures will presumably be introduced incrementally. Some public transportation systems already work on this basis.

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See Also: Automated Vehicle Guidance Systems; Automated Vehicle Monitoring Systems; Automobile Accident Avoidance Systems; Collision Avoidance Systems, Automobile; Emergency Response Systems.

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Induced Travel

New or expanded transportation capacity encourages people to travel more. That is the essence of induced travel. It can be associated with any mode of transport, and its existence has been recognized since before the automotive age, but attention and controversy have focused on induced car travel. In recent years, more precise measurement of induced traffic has accompanied proposals to acknowledge its effects on travel demand forecasting and hence on road construction plans.

The terminology of induced travel is not always consistent. "Generated travel" can mean the same thing, although some writers distinguish between new travel "induced" by new road capacity and travel diverted to the new route from other roads or other transit modes. Both new and diverted travel can call into question the benefits of new roads, but they raise different issues. Diverted traffic is best known through economist Anthony Downs's influential postulate of a "triple convergence" produced by new road capacity, which induces travelers either to switch the time of their trips, their route, or their transport mode. The switch in transport mode in particular raises the question of whether money spent on road construction might merely be subsidizing a shift from mass transit, to little net benefit.

Even broader questions arise where entirely new travel is induced by new roads. This new travel might comprise either longer commutes or additional trips. The most obvious cases are new suburban bypass highways that stimulate exurban residential or commercial real estate development. In many places these new roads have been built as economic development tools, with the intention of inducing traffic, that is, of drawing more motorists to planned new residences and businesses. Critics characterize these roads as subsidies for suburban sprawl.

When too many cars squeeze into too few lanes, congestion results. The obvious solution is more road space. Road construction has in fact been the reflexive response to congestion throughout the automotive age. During the 1920s, the first time that automotive traffic threatened to overwhelm city streets, some transportation planners observed that new roads seemed to attract so much new traffic that they failed in their purpose of relieving congestion. Their views had little effect on transportation policy, however. Car use was growing rapidly, and the fact that new roads quickly filled up was generally understood to mean that road capacity needed to expand even faster. During the rapid post-World War II expansion in auto ownership and road capacity, the same beliefs and policies continued to prevail, despite motorists' complaints that new freeways were filled to capacity as soon as they opened.

Induced travel becomes a problem when it calls into question the value of new road construction (or of new transit capacity). By the late 20th century, it was standard practice to calculate the economic benefits of new roads largely in terms of reduced

time lost to traffic congestion. However, critics pointed out that induced traffic might negate those gains, at least in part. Their slogan, “You can’t build your way out of congestion,” offered a direct challenge to the established logic of road construction. The difficulty in measuring induced traffic, in addition to the influence of vested interests committed to road construction, meant that these critics’ views long had little influence on policy.

Only since the 1980s have there been substantial efforts to measure induced travel. The question of whether it significantly altered traffic forecasts was long in dispute. Although there is no consensus about the precise elasticity of travel demand, statistical studies since the early 21st century have furnished increasingly persuasive evidence that it is measurable and significant—large enough to call into question some of the claimed reductions in congestion from new road capacity.

Transportation policy makers have generally been reluctant to acknowledge this evidence or to change their formulas for assessing the value of new roads. However, the traditional policy of “predict and provide”—that is, estimating traffic growth and building road space for it—has come under assault for various reasons, above all because many governments have found it impossible to pay for the continuing expansion of road capacity. Some critics point to evidence of induced traffic as a reason to limit road construction, because induced traffic accelerates the rate at which new roads reach their capacity.

Scholars and policy makers who accept the significance of induced travel have made various recommendations to reform transportation policy. The most obvious is to develop widely accepted formulas to predict the extent of traffic induced by proposed projects and to factor this induced traffic into any calculations of reduced congestion. Critics of road expansion argue more broadly that road construction should no longer be promoted as congestion relief. Advocates of road pricing believe that the problem would be solved if motorists had to pay an appropriate toll or fee for the privilege of speedier travel.

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See Also: Latent Travel Demand; Road Pricing Schemes, U.S. and International; Traffic Congestion; Travel Demand Forecasting; Triple Convergence.

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Information and Communications Technologies (ICT)

See ICT, Social Impacts of

Information Technologies and Transportation

Information technology is used in transportation for managerial, planning, and traveler purposes: operations (for example, running trains back and forth), maintenance (for example, repairing potholes), service management (ensuring safe and efficient road speeds), safety and security (monitoring and responding to potentially nefarious activities), and traveler information (maintaining mobility). This article identifies essential information technologies, current and emerging, for transportation.

Smart Infrastructure

Highways, streets, and arterials around the world are increasingly equipped with sensor technologies

to measure traffic throughput. Common sensor technologies include the following:

- Electronic tag readers placed at specific intervals determine travel time between specific points using the agglomerated data from all vehicles.
- Inductive loop detectors are in-asphalt vehicle detectors that count vehicles, often with classification type, as they pass over the loops, thus interrupting its electric flow. When two or more loops are spaced apart on the same road, they measure traffic speeds and throughput.
- In-road sensors in Germany are used to toll vehicles by calculating the vehicle weight, pollution class, and number of axles, while connecting to in-car sensors for billing.
- Traffic throughput data is used both to report speed and congestion conditions and, more recently, to predict traffic jams. An algorithm developed by IBM predicts traffic jams up to 45 minutes beforehand using this sensor data; in Singapore, this information prompts the adjustment of traffic lights to encourage traffic flow. As this prediction tool is further developed, it will likely be deployed elsewhere.

Next Generation Air Traffic Control (NextGen) is a U.S. initiative to replace air traffic controls from ground-base technologies to satellite monitoring. It will give airplanes more accurate depictions of their locations, reducing spacing requirements to make room for increased air traffic. In addition, air traffic controllers will be able to communicate through both voice and data transmissions, instead of the current voice-only system, allowing them to handle more aircraft and increase airport capacity. NextGen is presently being built and expected to be completed by 2025.

Computer-enhanced parking systems are being developed in several cities to improve the efficiency of the parking process. Sensors are placed in the asphalt in each parking space to alert spot-seeking drivers with smart phones of their availability. The sensors can also notify both car owners and traffic police of expiring time allotments. Some cities use the sensors to adjust parking rates by time of day

and incentivize side-street parking, and the systems allow drivers to pay by mobile phone.

Smart parking technology is still in development and faces several challenges:

- The sensors are not 100 percent accurate, leading to some errors.
- There is a delay in getting information from the sensors, through the processing servers, and out to drivers.
- Enticing drivers to look at their phones while driving presents a hazard to themselves, other drivers, and pedestrians.

Smart parking is being piloted in several major U.S. cities, including Los Angeles, San Francisco, and New York, and will likely be deployed more widely soon.

Bridges are vulnerable to cracks and erosion, among other defects, and must be monitored continuously to ensure their safety. Networks of sensors are placed on bridges to detect significant movements, corrosion, and cracks and to report that data to inspectors. The information is used in modeling software to determine the extent of the issue and whether repairs are necessary. This technology can help avoid a major catastrophe, such as a collapsed bridge.

Traffic Reporting

Traffic is reported to news outlets and the public by agglomerating information from several sources:

- Traffic alerts are developed by those with visual perspectives of the roadways, including helicopter-based reporters, traffic cameras, and bridge operators.
- Historical data lends perspective on typical rush hour commute times or traffic patterns during major events.
- Real-time information systems on major roadways use networks of roadway and vehicle sensors to measure traffic flows.
- Crowdsourcing gathers data from public mobile phones and the Global Positioning System (GPS) to measure traffic movement patterns in a region.

These data are collected and analyzed then reported to the public through news media, GPS data

receivers, and Internet tools such as Google Maps. They are also used to generate the information posted on highway variable message signs, which inform drivers of traffic news specific to their locations (for example, “45 minutes to downtown”).

Car and Road Technologies

New technologies are being developed that warn drivers of hazardous road conditions using wireless communications between road sensors and in-car dashboards so that, for example, icy pavement warnings may appear on drivers’ dashboard displays. In the future, roads may regulate car speeds or activate brakes to avoid collisions.

Vehicle-to-vehicle communications are also being developed so that cars become aware of one another as they drive in parallel lanes or navigate the same intersection. By integrating this perception into car control, this technology would allow for tight but adequate spacing between cars on highways, increased braking speed, and safer left turns at intersections.

Specific computer-assisted vehicle technologies currently in use include the following:

- *Radar.* Some cars currently host radar systems to detect close objects and alert drivers to other cars’ proximity and objects in their blind spots.
- *Lane detection.* In-car cameras detect lane lines and alert drivers who are drifting.
- *Infrared view.* In some Mercedes vehicles, infrared cameras detect objects ahead and display a depiction on the dashboard to alert drivers to obstructions farther on.
- *Electronic stability control.* When some cars’ computers detect skidding, they automatically apply the brakes to allow drivers to regain control. This technology is now required in all new vehicles in the United States and is already credited with saving thousands of lives.

Additional technologies in development include autonomous vehicles, which drive themselves based on computer system function rather than human operation, and are in development by automakers, software, search and mapping companies, government agencies, and universities around the world. The cars use information technologies to detect and

interpret roads and lanes, traffic lights, intersections, pedestrians, obstructions, and innumerable other factors of driving. Autonomous vehicles use cameras and 3-D imaging to recognize obstructions and foreign objects in the road, in addition to other cars, pedestrians, bicycles, and other moving objects, and predict their trajectories. This technology helps the vehicles anticipate and avoid collisions.

More than 90 percent of car collisions are determined to be caused by human error, such as distracted driving or incorrect predictions of other cars’ movement, but autonomous vehicles are expected to avoid major collisions through numerous calculations and predictions. As more autonomous vehicles take to the road, it is expected that more vehicles may fit on the road, as they will move more predictably and precisely, and eventually communicate with one another directly, thus enabling them to travel more closely together.

Several technologies powering autonomous vehicles have already been developed for the following prototypes:

- *LIDAR.* Google’s autonomous car uses a roof-mounted Light Detection and Ranging system (LIDAR), which uses spinning lasers to give the car a 360-perspective.
- *Predictive tools.* Mercedes’s car has two windshield-mounted cameras to create a 3-D image of what’s ahead and predict the objects’ movements.
- *In-wheel sensors.* Google’s car uses sensors in the wheels to detect velocity.
- *Infrastructure-based communications.* Vehicle-to-vehicle and vehicle-to-infrastructure communications use 5.9 GHz radio frequencies to communicate trajectories, proximity, and other essential driving components. Infrastructure-based communications will require major investments in infrastructure sensors and communications capabilities, which may be cost prohibitive.

Autonomous vehicles are in design around the world by major car companies and Google. Several major challenges are emerging, including regulation, liability, perception limitations, cost, and increased car use. Autonomous cars have not been legally regulated in the United States, except for burgeoning regulation in Florida, Nevada, and

California, where the cars are being tested on public roads and private tracks. Traditional regulations, such as speed limits, following-distance limits, and licensing requirements, must be adjusted for the new technologies that allow for safe travel at higher speeds, closer following distances, and unlicensed drivers. The National Highway Transportation Safety Administration is expected to release proposed rules by 2015.

Laws must also be adjusted for liability concerns; for example, if a car is speeding, is it the fault of the autonomous vehicle or its human operator? These questions abound when considering fault during incidents, among car, human operator, manufacturer, software designer, and third-party application designers.

Autonomous vehicle computers do not carry the same nuanced perception of surroundings as humans' brains do; for example, if the car is behind a stopped school bus, a human will expect children to cross the street immediately afterward, whereas a car may not have this perception. Self-driving automobiles will not be foolproof until they can "learn" from experiences.

The costs of these technologies are currently highly prohibitive for releasing the cars for mass consumption. For example, the LIDAR system costs \$70,000 per car; each technology component may raise the price of the vehicle excessively.

The increased attractiveness that autonomous vehicles would provide to driving long distances would lead to increased commute lengths, sprawl, emissions, and traffic congestion. The increased dependence on vehicles, rather than public transportation or walking in dense cities, would be detrimental to urban cores and environmental concerns.

Autonomous vehicles are expected to be launched with vehicle-to-vehicle and vehicle-to-infrastructure capabilities in 2018, with self-driving cars proliferating in 2025.

Public Transit Technologies

Transit bus fleets are typically tracked using automatic vehicle location (AVL), which gathers the locations of all buses and sends them to the management center. AVL is often a combination of GPS data-receiving technology and other, more specific, tools, such as signposts (roadside sensors that detect when a specific vehicle passes) or mobile phone network triangulation.



Inductive loop detectors, visible as rectangular outlines embedded in the asphalt of the M8 Motorway in Ireland, are used to count traffic between the towns of Cashel and Cahir, Ireland.

Though trains that operate solely above ground can use GPS data receiving systems similar to those for buses, underground trains like subways and commuter rails typically rely on track circuits. These somewhat simple tools maintain a series of circuits which, when passed over by a train, are de-energized, thereby making the system aware that a train is operating within that block. This information is relayed to a control center, which agglomerates all train locations for management of train movements. In many railroad systems, management can use automatic train control to slow or stop a train remotely in an emergency.

Aside from fleet management, a major output of bus and train tracking is passenger information systems, like countdown clocks or Internet applications that provide information to customers about the upcoming arrivals of their trains or buses. Real-time information has been demonstrated to improve the experience of transit riders and better their perception of their transit systems' operations.

Several subway systems around the world employ driverless trains through automatic train operation (ATO), which computerizes the movement of trains along a fixed route. ATO allows trains to travel closer together, since their movements are made more precise by the computerized system rather than by relying on human drivers' vision. However, most ATO-enabled subway systems retain drivers or other staff inside the train for passenger safety and emergency management. ATO results in real-time operations capabilities for transit managers and immediate information for passengers. The first partially driverless train was the London Underground's Victoria Line in 1968. Completely driverless systems are now currently being built out in Dubai and Singapore.

New innovations in transit fare payment systems have also allowed for multiple forms of payment:

Transit currency. Transit cards can be used for payment in a variety of places, including subway turnstiles, taxis, vending machines, and convenience stores. Most transit systems are moving toward a radio-frequency identification (RFID) enabled tap-to-pay system, while older models still require the swipe of a card.

City cards. Some cities, particularly in Europe, have launched highly successful cards used to pay for transit but also grant access to other city services, like public Wi-Fi, bicycle rentals, and libraries.

Mobile phones. Technologies being developed to enhance payments through mobile phones—including Google Wallet, Square, PayPal, and banking apps—make it possible to collect fare payments quickly and without requiring intricate internal systems for collection.

Open payment. The United States is experiencing a growing push to deploy open payment standards that allow any bank card or mobile device to be used for payment. These systems offer flexibility for future technological innovations but may limit future financial and business innovations by transit agencies.

Pedestrian navigation in cities is an area of increasing importance in technology development, as smart phones proliferate and users demand accurate, real-time wayfinding information to direct

them to their destinations. Using GPS data and cell phone tower triangulation, smart phones detect the locations of their users and provide walking, transit, and driving directions to their destinations. These smart phones have improved to provide spoken directions to users who are visually impaired, and interact with local landmarks to offer information and store discounts.

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See Also: Automated Road-Pricing and Toll-Collection Systems; Automated Vehicle Location Systems; Automated Vehicle Monitoring Systems; Automobile Driver Warning Systems; Electronic Route Guidance Systems; GPS; Incident Detection Systems, Automobile; In-Vehicle Computers; Next-Generation Airports, Federal; Railroad Automation Technology; Smart Highways; Traffic Detection Systems; Transit Fares, Media and Collection Systems and; Transit Information Systems.

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Inland Waterways, Freight Traffic and

Today, inland waterways are multifunctional, offering a variety of commercial and recreational uses as well as nature conservation opportunities.

Traditionally built for navigation and transportation, the introduction of rail and road haulage in many countries led to a downturn of water transportation and, with it, the inevitable but mostly reversible deterioration of the engineering, architectural, and landscape amenities associated with these routes. However, the increasing importance of securing sustainable development and green growth is leading to a revival in water transportation via inland waterways.

History

The earliest inland waterways, or canals, were created for the purpose of irrigation rather than for navigation. The first known example of a canal to improve the natural course of a river was the series of five canals that Pharaoh Pepi I built near the First Cataract of the Nile River ca. 2300–2180 B.C.E. The Phoenicians, Assyrians, Sumerians, Persians, and Egyptians all built various types of canals. The Chinese began a series of canals between the third and first centuries B.C.E., including one that joined two separate waterways, the Xiang and Lijing Rivers. This was the first contour transport canal and was devised for the transportation of military supplies.

In Europe, the Romans built canals in France, Italy, the Netherlands, and Britain, also for the purpose of transporting military materiel but mainly for irrigation. Through the use of rivers it was possible to extend seaborne trade many miles inland. The Romans built a canal at the mouth of the river Rhine to create passage for Mediterranean shipping. Following the collapse of the Roman Empire, inland waterways in Europe fell into disuse until commercial expansion in the 12th century saw a resurgence in river use and artificial waterway development. Rivers often provided the means for European explorers, traders, conquerors, or settlers, arriving in Africa, Asia, and the Americas by sea, to enter the interior of those continents. In many places, ports arose not only at the mouths of rivers but also at the so-called head of navigation, the highest point up a river that seagoing ships could reach into the interior. Examples of such ports include London and Calcutta.

A vast program of building, including monasteries, castles, and churches, took place in the Middle Ages, which led to further improvements of rivers for transportation of building materials. At the onset of the Industrial Revolution (ca. 1750–1850)

the network of land-based transportation was unsatisfactory, with the system consisting of either coastal shipping with its restrictions or horses and carts, which were unable to carry more than one or two tons of cargo at one time. This meant that the supply of commodities now in high demand—for example, coal and iron ore—was limited, keeping prices high and suppressing economic growth. The modern canal system in Europe was mainly a product of the Industrial Revolution as demand rose for a faster, economic, and reliable way to transport goods and commodities in bulk. It was private individuals, industrialists and prospectors, who were responsible for improving inland waterways and the development of the systems in Europe.

For example, the potter Josiah Wedgwood invested in canals, transporting the clay to his factory doors and his finished goods to market in Manchester, Birmingham, and farther away by water. By the height of “canal mania” there were over 4,000 miles of navigable inland waterways in Britain.

The new canals were built with a towpath alongside the canal for the horse to walk along. One horse was capable of pulling up to 30 tons at one time. Horse-drawn canal boats continued to be used, particularly in Britain, until the late 1950s, when they were replaced with steam- and diesel-powered boats. In Britain, an act of Parliament was required to authorize the construction of each new canal. Rival canal companies were formed and competed for canal construction in an area.

Canal-owning companies did not own or run a fleet of boats. They charged private operators tolls to use the canal. From these tolls they would try, with varying degrees of success, to maintain the canal and pay back initial loans. The boats used on canals were a mixed bunch, including flyers that carried light cargo and passengers at relatively high speed day or night and a variety of river craft. The main method of transportation on the canal system was the narrow boat or barge. These were owned and operated by individual carriers or by carrying companies.

Canals were built under constraints of engineering technology and finance. For these reasons the inland waterways constructed were often narrow in width and the standard dimensions of canal locks were 72 feet 7 inches (22.1 meters) long by 7 feet 6 inches (2.3 meters) wide. This limited the size of the boats capable of using these waterways

and limited the quantity of cargo they could carry. These factors ultimately led to the demise of inland waterways in Britain.

Decline and Conservation

By the mid-19th century railways began to threaten inland waterways. Railways could carry greater loads than canals; they could transport more people and move people and goods more quickly. In order to compete, canal companies were forced to cut their prices, reducing their profits and leading to reduced investment in the canals. By the latter part of the 19th century, rail companies began buying out struggling canal companies in Britain. Where canal companies resisted successfully, the pressure from rail transportation was in areas where the canals occupied niches in transport markets that the railways were not able to access, including supplying local markets, factories, and mills.

Parts of continental Europe, however, were proactive in protecting their inland waterways, making them more resilient to progress. France, Germany, and the Netherlands modernized their canal systems drastically between 1876 and 1899, widening them to allow larger boats, often capable of transporting up to 2,000 tons, to navigate along them. These waterways still offer an economically viable and competitive way of transporting freight. Most major industries in Britain that generate bulk transport needs today are sited on the coast. Although they cannot enjoy direct access to inland waterways nationally, they do take advantage of the waterways in other European countries by use of modern river-sea ships and modern barges.

In Britain, the canal system was nationalized in 1948 under the British Transport Commission. Freight transport declined rapidly in the 1950s and 1960s with mass road transport, and increasingly, canals were abandoned due to falling traffic. In 1963 the decision was made to formally cease commercial carrying on the canals. However, recreational use of canals in Britain has steadily increased as people's leisure time and disposable income increased. The social, economic, and environmental benefits of inland waterways is once again being recognized. Inland waterways are being valued as part of Britain's landscape, the need to protect and the ability to enjoy their industrial heritage and archaeology, for their contribution to urban landscapes and the unique habitats and ecosystems they support, and

for the varied leisure and recreational activities they offer. As a result of this, the Inland Waterways Association (IWA) was formed. The IWA advocates the restoration, conservation, maintenance, and sensitive development of the inland waterways of England and Wales and promotes the use of inland waterways for recreational and commercial purposes.

United States

There are more than 12,000 miles of inland and intracoastal waterways in the United States. These waterways are found in 38 states and handle approximately half of all inland waterway freight (or one-twelfth of all national freight). According to the U.S. Army Corps of Engineers (the Corps), which is responsible for the operation and maintenance of these waterways as part of its civil works program, the network transports around 600 million tons of domestic cargo movements every year. Commodities shipped in the United States via inland waterways include petroleum and petroleum products (approximately 310 million tons), coal, food and farm products, chemicals, aggregates, machinery, and equipment.

The inland waterway system developed gradually throughout the nation's history and predates the founding of the nation itself. Before the onset of rail and highway transport, inland waterways were a primary means of transporting bulk goods. Early canals were followed by river improvements, such as clearing obstructions and dredging, which provided a safer channel for commercial navigation but were still subject to extreme variations in water levels. Locks and dams were constructed to raise water levels and provide a more reliable channel on rivers such as the Ohio, the Illinois, the Upper Mississippi, and the Tennessee. Through the early 1800s, inland waterway development was left to the states, until the U.S. Supreme Court affirmed the constitutional federal authority over interstate commerce in 1824. Shortly thereafter, the federal government began to provide funding and support to these waterways to improve interstate and international commerce.

The Corps is responsible for navigation channels, harbors, locks, and dams, and it maintains and regulates channel depths through dredging and water management. Costs for maintenance and construction of inland waterways are funded



A barge transporting cargo under the Fremont Bridge, which carries an interstate highway over the Willamette River in Portland, Oregon. The 12,000 miles of U.S. inland and intracoastal waterways help transport as much as 600 million tons of cargo around the country every year. With an overall 13 percent rise in ships arriving at U.S. ports in 2010, the United States anticipates growth in inland waterway freight traffic that may strain the antiquated infrastructure of existing canals and locks.

by the Corps through appropriations and by the commercial user industry through user fees paid to the federal government. The Corps pays 100 percent of the cost for studies and for operations and maintenance on the inland waterway system, while the Water Resources Development Act 1986 provided that expenditures for construction and major rehabilitation projects on inland waterways are to be cost-shared on a 50/50 basis between the federal government and users through the Inland Waterways Trust Fund (IWTF).

Congress is faced with competing proposals relating to future financing for inland waterways. Improvements in rail and highways have decreased reliance on inland waterways as a means of commercial freight transportation, although this situation is expected to change. The Department of Transportation's "Freight Analysis Framework" (2007) has forecast a 70 percent increase in freight traffic by 2020. Highways, railways, and waterways will all be impacted. Waterways pose an efficient and sustainable mode through which to manage this

increase, particularly when considering the benefits associated with water transportation. However, the United States is faced with significant cost implications to get the inland waterways up to speed due to their age and lack of investment and maintenance; presently, the 50-year-old federal locks still operating are at the end of their expected life span, reducing reliability and capacity in the inland waterway infrastructure.

In addition, with the number of ships calling at U.S. ports rising by 13 percent in 2010, the pressure on U.S. inland waterways is set to increase. A report indicates that following the completion of the expansion to the Panama Canal to accommodate 366-meter-long ships with a 15-meter draft, the canal will make it easier for Asian ships to reach America's East and Gulf Coasts. The forecasted increases in shipping are considered to offer an efficient mode of transport, with a single barge having the equivalent dry-cargo capacity of 16 railcars or 70 trucks and the liquid-cargo capacity of 46 railcars or 144 trucks.

Other International Examples

Other countries seeing a rise in volumes of cargo transported by inland waterways include China, India, and the countries of southern and eastern Africa, all of which benefit from considerable lengths of navigable rivers.

China's inland waterway network is the largest in the world. It has a navigable length of 123,495 kilometers and consists of over 5,000 rivers and tributaries. In 2007 China's inland waterways transported 1,180 million tons of cargo, compared with waterway cargo of 800 million tons in the United States and 500 million tons in the European Union. The Yangtze River is the largest waterway with the Pearl River and Hangzhou-Beijing (known as the Grand Canal) waterways. The Pearl River Waterway is an important transportation link between Hong Kong and the manufacturing areas of Guangdong, while the Grand Canal is the longest human-made waterway in the world, extending 1,743 kilometers.

In India there are 14,500 kilometers of navigable waterways. The Inland Waterways Authority of India (IWAI) was established in 1986 under the Inland Waterways Authority of India Act of 1985 for the development and regulation of inland waterways for shipping and navigation. It is responsible only for the declared National Waterways, of which, there are five. The IWAI undertakes projects for development and maintenance of waterways infrastructure on national waterways using a grant received from the Ministry of Shipping. Data on cargo movements in India indicates a more than 100 percent increase in the volume of goods transported by inland waterways between 2003 and 2010.

The Community of Eastern and Southern African States (COMESA) has resolved to revive inland waterway transport and increase trade between the countries, bringing them together. This has led to an expansion of trade between COMESA countries from \$3.1 billion in 2000 to nearly \$9 billion in 2007. The Great River Nile Co., founded by Captain Abdelkader Saeed, proposes the use of the river Nile in inland cargo movement. Door-to-door services are included in the project, which would incorporate inland road transport links only between seaports and river docks. This project would reduce transportation costs and time and relieve burdens on roads, as well as reduce emissions of greenhouse gases.

Conclusion

It appears that the development of inland waterways as a viable mode of freight transportation is being reinvigorated. Long-standing waterways are being modernized to accommodate the larger modern water barges and ships; this is illustrated by the engineering changes to the Panama Canal and the proposed changes to the Suez Canal (which connects the Nile and the Mediterranean Sea with the Red Sea), which today supports 8 percent of the world's shipping traffic. While reviving and improving the canal network in Britain is less likely, the U.S. Congress is in a position to ensure that the protection and improvement of the inland waterway system enables the network to compete alongside rail and road haulage as freight volumes increase.

There are a number of advantages to using inland waterways and barge transportation that should not be overlooked, particularly in the age of austerity and green growth. Barges emit less greenhouse gases and use less fuel, which lowers transportation costs. Transportation and travel by inland waterways causes fewer deaths and creates less noise and other nuisances due to their location away from human settlements. Even where canals need to be widened or restored, research in Germany has shown that of total external environmental costs of the various freight transport modes, water transport has much lower environmental costs.

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See Also: Environmental Impacts; Harbors and Ports, Administration and Operations of; Inland Waterways, Passenger Traffic and; Railroads, Freight; Ships.

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Inland Waterways, Operations and Management

The U.S. inland and intracoastal waterway system is not as well-known as its airway, railway, or highway networks, but inland waterways are an essential and often overlooked part of America's freight transportation system, handling approximately 600 million tons and 300 billion ton miles of domestic cargo shipments per year. Inland waterways are the primary artery for more than half of the nation's grain and oilseed exports, for about 20 percent of the coal for utility plants, and for about 22 percent of domestic petroleum. Most of the cargo is raw materials and liquid and bulk cargo such as coal, petroleum, chemicals, grain, processed metals, food, farm products, and cement, sand, and gravel. The U.S. Army Corps of Engineers (USACE) has overseen and maintained the waterways since the 19th century, but in the 21st century, politics and special interest groups as well as economic pressures have affected the oversight and modernization of the inland waterways.

Demand for freight transportation in America is escalating. The U.S. Department of Transportation's "Freight Analysis Framework" report forecasts a 70 percent increase in freight traffic by 2020. Traffic on inland waterways is forecasted to increase by 51 million tons of freight from 2012 to 2020, and by 2040, the increase is expected to exceed 118 million tons. This growth will challenge the capabilities of all transportation systems, especially highways, but it will also impact rail and water transportation. The marine ports system is especially important for

America's international trade, valued at more than \$944 billion in imports arriving in the United States by water. America depends heavily on waterborne trade for its growing export markets, especially agricultural products, manufactured goods, and energy and refined petroleum products. Even if growth slows worldwide and Europe continues to undergo economic problems, U.S. trade with Asia and Latin America and growth forecasts require major investments in U.S. marine ports and waterways.

History

As early in American history as 1797, George Washington and Benjamin Franklin recognized the importance of waterways in developing the country. The portal canal at the Great Falls on the lower Susquehanna River was the first working canal in Pennsylvania and one of the first in the new country. Then, as America expanded so did its canal system, supported by river improvements like clearing obstructions and dredging safer channels. Private and public companies constructed a system of locks and dams on the Ohio, Illinois, Mississippi, and Tennessee Rivers and many of their tributaries.

President Thomas Jefferson authorized a Corps of Engineers to be stationed at West Point on March 16, 1802, an act that led to the creation of the modern U.S. Army Corps of Engineers (though the organization had existed since 1775). The General Survey Act of 1824 authorized the use of Army engineers to survey road and canal routes, and in the same year, Congress passed legislation to remove sand bars from the Ohio River and snags on the Mississippi and assigned that responsibility to the Corps of Engineers. Today, the USACE manages America's more than 25,000 miles of inland waterways and the 12,000 miles of commercially important waters.

Maintenance and Repair

The inland waterway system is aging, with the average age of its 192 commercially active locks now over 50 years old. Many of the functioning locks and dams were built in the 1930s, including a majority of the locks on the Upper Mississippi, Illinois, and Tennessee Rivers, and they need modernization or major rehabilitation. Even the "second generation" Ohio River higher lift locks and dams were built in the 1950s. Older structures like the George Washington and the San Francisco–Oakland Bay Bridges can enjoy a long traffic life as long as they

are maintained, rehabilitated, and modernized, but the USACE reports that in dollar terms, funding for inland waterways infrastructure has been flat or declining for decades even as the structures age.

Commercial towboats pushing barges lashed together as tows make up the majority of the inland waterway traffic. Each barge has a capacity of 1,400 to 1,800 tons of cargo, and a single 15-barge tow carries the freight car equivalent of 870 tractor trailer trucks, creating an inexpensive and fuel efficient method of freight hauling especially suited to bulk cargo that is not time sensitive. Lock and tow size and condition are critical factors in determining the amount of cargo that can pass through a lock over a set amount of time. Many modern tows operate with 12 or more barges passing through a 600-foot lock, requiring the tow to be divided into two sections to pass the lock, which can be time consuming and cause long lines of tows waiting to move through the lock.

The USACE began to modernize the locks on the Ohio River in the 1960s, adding 1,200-foot chambers that can pass a typical tow in a single lockage. In the decades since the 1960s, the Corps of Engineers has constructed a new dam with twin 1,200-foot locks at Olmsted, Illinois, at the juncture of the Ohio and Mississippi Rivers, and a second 1,200-foot chamber at McAlpine Locks and Dam near Louisville, Kentucky, as well as the Kentucky Lock on the Tennessee River and the Inner Harbor Lock on the Gulf Intracoastal Waterway at New Orleans, Louisiana. The Corps also has ongoing projects in other states and several major rehabilitation projects, including modern navigation facilities and investment in environmental restoration and management. These projects represent an investment of over \$3.5 billion in inland water modernization over the next decade.

There are several key navigation improvement feasibility studies of the current inland waterway system, including one of the Upper Mississippi River and Illinois Waterway, the Ohio River, the Gulf Intracoastal Waterway, the Black Warrior River, and the Tennessee River, which are expected to pinpoint navigational and environmental actions necessary to support the inland waterway system.

Lock Performance and Competitiveness

The lack of adequate funding has changed the nature of maintenance programs from preventive

maintenance to a fix-as-fail policy. A lock malfunction taking weeks to fix can produce major consequences for barge traffic and for manufacturers dependent on receiving their cargo in a timely fashion. Contrasted with the decline in civil works investment, the USACE reports an increase in the backlog of needed maintenance and repair of individual projects. As funds have dried up, the Corps has been addressing only the most urgent maintenance and repair projects and postponing the others, estimating that more than half of the repairs were navigational.

Lock performance data from the Lock Performance Monitoring System of the Corps of Engineers indicates that lock down time has more than doubled over the past decade and data for locks on the Upper Mississippi River suggests that increasing time for unscheduled lock maintenance and mechanical malfunctions are the main reasons for the unavailability of locks. In 2009, about 90 percent of locks and dams on America's inland waterway system experienced unscheduled delays. Maintaining existing levels of lock operation will cost \$13 billion in total investment needs by 2020, and an additional \$28 billion by 2040. Current funding levels can support only \$7 billion by 2020, and an additional \$16 billion by 2020. About 27 percent of these needs involve constructing new lock and dam facilities.

Continuous unavailability of locks will seriously impact the viability of the inland waterway system for freight transportation as shippers concerned over lock unavailability, unreliability, and system integrity may decide to ship by rail or highway. On a system-wide basis, waterways are generally more energy efficient and produce fewer air emissions than land freight, which provides the rationale and national interest for preserving them. Current fiscal and maintenance policies may seriously impact the future of the inland waterway system.

America's manufacturers are able to ship goods efficiently throughout the country and export them overseas to keep the country competitive because of a diversified transportation network operating on land, sea, and air. The transportation cost savings from inland waterways shipping is estimated to exceed \$7 billion annually compared to the cost of shipping by other methods. Frequent planned or unplanned closing of aging locks because of mechanical failure or regularly scheduled maintenance on the inland navigation system create costly

delays and contribute to the further deterioration of the system.

Economics of Maintenance

Although economic factors motivate many port authorities simply to maintain their existing conditions to fulfill customer needs and requirements, they are compelled to plan improvements as well. They project spending a combined \$18 billion through 2016 on infrastructure improvements for water terminals while their private sector terminal partners anticipate spending a combined \$27.6 billion for a total of nearly \$46 billion.

Accommodating the massive new Panamax cargo ships that will ply the enlarged Panama and Suez Canals will be a major challenge for U.S. ports, especially those on the East Coast. To meet anticipated growth in trade and domestic waterborne traffic, public investment will need to be more than \$30 billion dollars by 2020. This includes navigational dredging and operation and maintenance needs for both marine dredging and inland waterways and marine ports, but the figure doesn't include private sector investments to improve the port facilities themselves or the connections to roads and rail systems to reduce traffic congestion caused by trucks entering and leaving port facilities.

Funding needs are expected to reach \$92 billion by 2040, which will leave the United States with a funding gap of nearly \$46 billion based on current investment trends and the USACE annual budget. More than 61 percent of the identified need and funding gap is intended for marine navigation and operations and maintenance, and about 39 percent for inland waterways.

The U.S. economy depends on low export transportation costs to offset higher wage levels and production costs compared with its competitors. Expensive export costs for goods will affect the competitiveness of the United States in global markets. This is already happening in a small number of industrial sectors and could worsen in the future.

USACE Inland Waterway Study

The 2008 USACE publication, "Great Lakes and Ohio River Navigation Systems Commerce Report," notes that of the more than 25,000 miles of inland, intracoastal and coastal waterways, the federal government improves and maintains almost 11,000 miles, or about 45 percent of the total channel

length, including dredging and installing and maintain navigation structures like locks, dams, dikes, and revetments.

Federal and state governments and port authorities and carriers share responsibility for the nation's waterway transportation system. The inland waterway transportation industry features extensive cooperation and coordination between public and private sectors and the USACE facilitates the waterway navigation projects that ensure safe passage for vessels.

The USACE Institute for Water Resources prepared a study titled *Waterways Modernization: Preparing for Post-Panamax Vessels*, which used in-house specialists, visiting scholars, and experts in deep draft navigation and inland navigation districts. The study provided advice for Congress on how to address the critical need for additional port and inland waterway modernization to accommodate post-Panamax vessels when the Third Set of Locks Project to double the capacity of the Panama Canal is finished in 2015. Marine experts are certain that the Panamax vessels will shape the direction of intermodal freight logistics in the United States, especially in trade flows, ship sizes, volumes, transshipment port development, and in which U.S. ports will benefit by the new locks. The timing and scope of these future logistics depend on present actions and legislation.

Financing the Inland Waterway System

Since inland waterways are an important part of America's transportation and economic system, the federal government has invested in navigation infrastructure since its creation, and has supported commercial barge shippers and other waterway users by funding operational costs, capital expenditures, and major rehabilitation projects on inland waterways.

Inland waterway users are not charged tolls, but since 1978 the Inland Waterways Act has imposed a barge fuel tax on commercial users to maintain and improve waterway structures and facilities. The act also established the Inland Waterways Trust Fund (IWTF), appointing the U.S. Treasury to hold the funds, which are used to cover half the cost of new construction and major rehabilitation of the inland waterways infrastructure. In 1980, the barge fuel tax was set at 4 cents a gallon but was gradually raised to 10 cents per gallon by 1986.

The Water Resources Development Act of 1986, a wide-ranging bill concerning waterway transportation, established the Inland Waterways Users Board to recommend construction and rehabilitation priorities and spending rules for the inland waterways. It established a 50/50 cost shared basis for projects between the federal government and commercial users and fixed federal government responsibility for operations and maintenance costs at 100 percent. It also gradually increased the fuel tax to 20 cents a gallon by 1995.

The inland waterway system faces an uncertain funding future. The fund's balance has declined significantly since 2005 for reasons that include increased appropriations, cost overruns, and decreased revenues. If the current financing system is not changed, IWTF spending will have to be curtailed. The USACE estimates that by 2020, maintaining the current levels of unscheduled delays on inland waterways without making them worse will require more than \$13 billion, with current funding levels expected to reach just \$7 billion. About 27 percent of these projects involve constructing new lock and dam facilities and 73 percent are needed to rehabilitate current facilities.

The time needed to complete USACE projects drives up the cost and creates a project backlog because declining tax revenues have created a stagnant funding scenario for the Corps. If funding levels continue to decline, the Corps estimates that 22 major construction and rehabilitation projects will not be complete until 2090. In recent years, a trend toward cost overruns and project delays have been important factors in the decline in the IWTF. The Corps acknowledges that it needs to create a new national strategy.

Investment in Inland Waterways

In a 2009 report, the American Society of Civil Engineers (ASCE) concluded that America's infrastructure is close to failing and called on the president and Congress to adopt a long-term, systematic approach to improve its condition and performance. ASCE found that 47 percent of all locks that the USACE maintains were classified as functionally obsolete in 2006. If there are no new locks built within the next two decades, another 93 existing locks will be obsolete by 2020. As waterway use increases and the current system continues to age, with many locks beyond their design life of 50

years, the deteriorating condition of the system will impede recovery from natural or manmade disasters and threaten the American economy.

The ASCE stressed that America's inland waterways are strategic economic and military resources because they are capable of moving large amounts of cargo. The U.S. Army War College contends that the strategic contributions of these inland waterways are not well understood and this lack of understanding affects decisions about their management, funding, and integration with other national transportation systems. A better understanding of the inland waterway system will help build an effective transportation network for the 21st century.

Government Plans

The George W. Bush Administration proposed a plan to phase out the inland waterway barge fuel tax and institute a lock fee resembling a toll, and the Obama Administration recommended replacing the fuel tax with user fees that would have increased revenues and mandated more spending on inland waterways projects in fiscal years 2010 through 2013 and fiscal year 2014. Congress and industry interests rejected each of the proposals. The National Association of Manufacturers (NAM) opposed both Bush and Obama administration traffic proposals on the grounds that a new fee will lessen the competitiveness of the inland waterway transportation system and negatively impact the major industrial and agricultural waterway shippers using the Upper Mississippi, Ohio, Illinois, and other rivers.

Acknowledging that the present system of locks and dams requires billions of dollars in increased investment, the NAM also pointed out that no long-term capital plan to guide system-wide investments exists. Inland waterway projects currently take from 10 to more than 20 years to complete, an unnecessarily long time period that increases construction costs and adds delays to the system. Projects routinely experiencing cost overruns averaging almost 120 percent more than Congressional revenue authorizations are also unsustainable.

In April 2010, the Inland Waterways Users Board, (IWUB), a committee advising the USACE on inland waterways, endorsed an alternative proposal that many barge industry interests support. The plan prioritized completion of navigation projects across the system, sought to improve the

government's management and delivery of projects to help control costs, and recommended an increase in the diesel fuel tax from 20 to 29 cents a gallon to help finish 25 projects in the next 20 years. It also recommended that federal and local authorities continue equally sharing the cost for projects totaling more than \$100 million but suggested that the federal government cover the full project costs for new dams and rehabilitation projects costing less than a \$100 million. The board estimated that its plan would provide \$7.6 billion in new revenues over 20 years. NAM recommended that Congress support implementation of the plan in the Water Resources Development Act authorization.

The barge industry and agricultural groups argue that the changes are necessary to bolster the trust fund, improve deteriorating infrastructure, and distribute costs of the waterway system more equitably. The Obama administration agreed that waterway infrastructure systems need to be upgraded but favored higher user fees instead of shifting the costs to the federal government. Some taxpayer and environmental groups favor increasing non-federal costs and not just construction costs but also operation and maintenance expenses that are not currently shared.

The Water Resources Development Act

The USACE planned and developed the Water Resources Development Act (WRDA), a biennial legislative package that is the means for water projects to be studied, planned, and developed. Passed for the first time in 1974, it is also the legislative vehicle for implementing policy changes in the water resource projects and programs that the Corps has undertaken.

The Water Resources Development Act of 2013 would authorize the project delivery recommendations of the Obama administration proposal, but it would not change the existing fuel tax or cost sharing arrangement. The Obama administration's fiscal year 2014 budget also proposed a new, unspecified user fee expected for inland waterways. As it considers inland waterways legislation, Congress may debate the appropriate cost sharing between the federal government and waterway users for various inland waterways costs, the appropriate user fee to fund the nonfederal share, including fuel taxes and lockage fees, and the preferred planning process and funding levels for inland waterways.

The current WRDA bill has sparked controversy from both Democratic and Republican legislators. Its provisions include effectively requiring a tripling of the amount that the federal government spends for harbor maintenance and related work, which would mean a \$15 billion increase in spending over the next 10 years. It would eliminate cost sharing for maintaining channels deeper than 45 feet, a key provision in the Water Resources Development Act of 1986, and expand the federal role in other areas that previously had always been nonfederal responsibilities. The bill also would establish an annual per vessel fee to raise \$1.1 billion in additional revenue over 10 years from commercial users of inland waterways.

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See Also: Harbor and Port Planning; Inland Waterways, Planning and; Inland Waterways, Traffic Management and.

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Inland Waterways, Passenger Traffic and

Ferries are boats and ships that carry passengers, cargo, or vehicles across a body of water, and generally operate on a regular schedule ferrying back and forth for a portion of the day. In some cases a ferry may be the primary or only means of transport between two points and constitute part of the public transportation system, as in many island communities and cities on the water.

In New Orleans, ferry service has been part of the transportation system since 1823, predating the streetcar system by 12 years. New Orleans is located at a bend in the Mississippi River and is bordered by two lakes, Lake Pontchartrain in the north and Lake Borgne in the east. Ferries were used to transport passengers and goods back and forth between the East and West Banks of the Mississippi River, with a regular ferry schedule established in 1827 between Canal Street (just outside what is now known as the French Quarter) and Algiers, the community on the West Bank. Today this is one of the oldest operating ferries in the country. More ferries were added in subsequent decades as the city spread out along the riverbanks. A railroad ferry added in the 1850s became obsolete with the construction of the Huey P. Long Bridge, a railroad and vehicular bridge across the river, built in 1935. Private ferry service declined in the 20th century after the Greater New Orleans (GNO) Bridge was built, providing another vehicular bridge across the Mississippi.

The GNO was operated by the Mississippi River Bridge Authority, which acquired the main public ferry lines in the area—the Algiers Ferry, the Gretna Ferry, and the Chalmette Ferry, which connects two state highways. Control of the ferries

was later passed to the Crescent City Connection Division of the Louisiana Department of Transportation and Development. Tolls of \$1 per automobile are charged, but only from the West Bank to the East Bank. Westward trips, as well as all trips for bicycles and pedestrians, are free. Today, New Orleans has the busiest ferry system in the country outside of Washington State and New York City, with most passengers using it as part of their daily commute.

A number of ferry services operate in the New York City area. New York Water Taxi offers commuter service along the East and Hudson Rivers. Seastreak offers commuter ferries from Monmouth County, New Jersey, to Manhattan, as well as service to some of the home games at Yankee Stadium and weekend service to Martha's Vineyard. The New York Beach Ferry operates weekend and holiday service to Rockaway Beach in the summer. There are also several companies offering sightseeing ferry trips in the city area.

The largest ferry operation in the country is the Staten Island Ferry, with a daily ridership of about 75,000. Ferry service between Staten Island and southern Manhattan began in the 18th century, with individual sailors transporting passengers on two-masted sailboats. Motorized ferry service was offered in the 19th century by steam engine tycoon Cornelius Vanderbilt, and city government assumed control of the ferry service in 1901 after a ferry collision left five dead. Operated by the New York City Department of Transportation, the Staten Island Ferry consists of eight vessels ferrying back and forth between Staten Island and Manhattan. The ferry runs 24 hours a day, 365 days a year, and carries only passengers and bicycles, for free. Until stricter transportation security regulations were enacted following the September 11, 2001, terrorist attacks, the ferry also transported vehicles for a \$3 toll. Commuter parking is available at the Staten Island terminal. In the past, the ferry charged for passengers, though it was always cheap—in 1975, the fare was a quarter, less than half of the city's cost to operate it. The fare increased to 50 cents in 1990, but since 1997 no fare has been charged.

Though primarily operated for the sake of commuters, the Staten Island Ferry is a popular tourist attraction because of its view of the Statue of Liberty and the Manhattan skyline at night. It has become one of the icons of the city, appearing in the



The New York Waterway company's East River Ferry is underway near the Manhattan Bridge in New York City, July 2013. It is one of a large number of ferry services operating in New York City and its surrounding waterways.

opening credits of David Letterman's nightly television talk show, in the Melanie Griffith film *Working Girl*, and in the opening montage of Woody Allen's film *Manhattan*. The Staten Island terminal does not connect to commuter rails to other boroughs, though connections may be made by first taking a Staten Island bus.

In Washington State, the Pacific Northwest state's unique geography has made ferries indispensable. Numerous inland waterways run through the Puget Sound area, which has a number of inhabited islands and peninsulas. The waterways played a major role in the settling of the area, providing natural transportation routes, and steamships began operating in the Sound in the 1830s, before the town of Olympia had even been founded. By the end of the 19th century there were 40 steamboat routes on the Sound, most of them operated by

a boat purpose-built for it. The "mosquito fleet," as it was called, dwindled in the 20th century as automobiles became common.

Today, many of the ferries serving Puget Sound and the San Juan Islands are operated by Washington State Ferries (WSF), the largest ferry fleet in the country and third largest in the world. Owned and operated by the Washington State Department of Transportation, WSF transports 11 million vehicles a year, more than any other ferry system in the world. It grew out of the state's purchase of the fleet of the Black Ball Line, one of the operators of the old "mosquito fleet." It consists today of 22 ferries carrying people and automobiles, on eight routes that are legally part of the state highway system, though most have no traversable road component.

Washington includes numerous other ferry services, including the Guemes Island Ferry, the Wahkiakum County Ferry, the Gifford-Inchelium Ferry, the Steilacoom-Anderson Island Ferry, a Washington State Department of Corrections Ferry for service to the McNeil Island Corrections Center, the Hat Island Ferry, and many private ferry services for island residents.

Other major ferry services in the United States include the ferry fleets in San Francisco, serving tourists and commuters in the Bay Area, and the Alaska Marine Highway System, which operates among the Aleutian Islands and the Inside Passage of Alaska, as well as providing transportation to and from neighboring British Columbia, Canada. Part of the National Highway System, the Marine Highway System is state and federally funded. Mainland routes provide service to Bellingham, Washington, providing some of the limited transportation of vehicles from Alaska to the lower 48 states without passing through Canada or requiring a passport.

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See Also: Ferries; Inland Waterways, Freight Traffic and; Inland Waterways, Navigation of; Inland Waterways, Planning and; Inland Waterways, Traffic Management and; Ocean Passenger Travel.

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Inland Waterways, Planning and

The U.S. inland waterways system is a valuable component of the national transportation system, transporting bulk freight commodities such as coal, corn and wheat, oil and oil products, heavy manufactured goods, and aggregates. The contribution of waterborne transportation to the national economy is expected to grow significantly over the coming decades. The inland waterways system consists of two principal types of waterways: the Western River system, composed of the Mississippi River system and the Columbia–Snake river systems, and the intracoastal waterways adjacent to the Gulf and East Coasts. In total, the United States has over 12,000 miles of commercially navigable rivers and intracoastal waterways, serviced by 192 commercially active locks and their associated dams.

U.S. Army Corps of Engineers

Inland waterways transportation infrastructure is unique in that it is almost exclusively federally regulated, constructed, and maintained. The U.S. Army Corps of Engineers (USACE) serves as the primary manager of river navigation infrastructure in the United States, having responsibility for lock and dam construction and maintenance, channel dredging, and reservoir pool maintenance. The federal government operates and maintains 185 of the navigational locks on the inland waterways system.

Management of the system is both costly and complex. The USACE is required to maintain a proper water level and ensure that river systems, such as the Mississippi River, the Ohio River, and the Columbia–Snake Rivers and their respective major tributaries, are navigable under all weather

and river conditions. In addition to overseeing the building and maintenance of dams and locks, the USACE dredges channels to a navigable depth and deepens coastal and inland ports to accommodate commercial vessels.

The number, size, and placement of lock and dam infrastructure can impact the type of commodities being shipped on the waterways. Locks vary in length between 600 feet and 1,200 feet. The larger locks, being able to handle more barges, expedite the speed with which tows can transit a lock by reducing waiting times at locks.

The sizes of tows vary depending on the physical characteristics of the river, the number of locks, and the lock chamber size. For instance, the Ohio River can handle tows with 15 barges, while the Lower Mississippi River has no locks and can accommodate tows of 40 or more barges. Smaller tributaries, such as the Arkansas River, have conditions that greatly limit the size of tows. North of St. Louis, the Upper Mississippi River has many locks, which can accommodate only smaller tows, requiring barges to break tows into smaller groups to allow safe passage through the locks. Another consequence of this geography of lock and dam systems is that most manufactured products, shipped via container-on-barge, are not shipped north of the Port of Memphis. Sections of the Western River system with a high number of lock and dam infrastructure better accommodate the shipping of large bulk commodities, such as coal, aggregate, grain, and fertilizers.

As an agency within the Department of Defense, USACE is funded by the federal government and performs its duties as authorized by Congress. In addition to providing efficient navigation, the federally maintained waterways infrastructure facilitates other uses of water resources, including drinking water, irrigation, flood control, recreation, and fisheries.

Infrastructure and Funding Crisis

The inland waterways infrastructure of dams, locks, and channels is aging. Many of the locks and dams are between 50 and 75 years old and in need of repair or replacement. There is a need for regular and intensive maintenance for many of these locks to fend off a system failure. Given the expected expansion of waterborne commerce on the system—more than 20 percent by

2030—many of the locks are in need of expansion in order to accommodate and expedite the movement of large tows.

Due in part to the long and successful history of the infrastructure built and maintained by the USACE, the public tends to take for granted the positive contributions of the inland waterways and underestimates the level of resources required to maintain lock and dam infrastructure. Beyond transport, the inland waterways and reservoirs operated and maintained by the USACE provide a broad range of benefits to a variety of users. The occasional disruptions to these benefits, such as lock closings and flooding, tend to focus public attention on the benefits of the inland waterways infrastructure. Even relatively minor disruptions—such as problems that require the lowering of water levels of rivers, reservoirs, and lakes—can remind people of the importance of the infrastructure. Individuals and businesses that rely on the waterways systems' value for transport, water supply, and recreation, often take note during severe low-water events.

Lock failures have the potential to wreak devastating impacts on industries reliant on waterborne transportation for dependable delivery. The failure or structural compromise of a USACE-managed infrastructure component or the closing of a navigable waterway could result in many economic impacts to both the public and commercial sectors. For example, a lock failure could interrupt or curtail commodity movements across a broad section of the system and have dire local impacts as commodities are transferred to other transportation modes; industrial customers lose access to inputs and commercial customers lose access to finish products. Secondary impacts could also multiply quickly: employment may drop, traffic congestion and highway impacts may increase, and even industries farther away may be impacted by a shortage of inputs or higher priced inputs.

The economic impact of a disruption in the inland waterways transportation system becomes even more costly when the nature of the primary waterborne commodities is considered. The economic ripple effect for infrastructure failure is especially notable for commodities such as coal, used in the many power plants adjacent to rivers to generate low-cost electricity, and staple grains such as wheat and corn. Most coal-fired power plants maintain

a 60-to-90-day supply of coal; however, long service disruptions in lock infrastructure could likely lead to very high spikes in electricity cost within a region. High food prices would also be likely, as many crops and agricultural inputs, such as fertilizers, are shipped via barge.

Cost of Modernizing and Repairing

The infrastructure needs of the system over the next 20 years were recently studied by the Inland Waterway Users Board, comprising a key set of waterways stakeholders. Authorized by Congress in the Water Resources Development Act of 1986, the board is made up of waterborne freight carriers and shippers with the express goal of providing advice to the USACE regarding infrastructure needs on the inland waterways.

In 2010, the Inland Waterway Users Board established a subcommittee to complete a comprehensive review of investment needs for the rehabilitation of the U.S. inland waterways system and to make recommendations for restructuring the current funding mechanisms. The Inland Marine Transportation Systems Capital Investment Strategy Team (IMTS-CSS) was composed of members from the Inland Waterways Users Board and USACE staff. In its report, titled "Inland Marine Transportation Systems Capital Projects Business Model," the IMTS-CSS recommended to Congress that it implement changes to the budgeting and selection processes for improving and expanding inland waterways infrastructure.

Due to rising costs for dam and lock projects, the report called for a large increase in infrastructure investment along with changes in the funding of projects. The report called for an increase of \$380 million per year for the next 20 years to fund new construction and rehabilitation projects.

Maintenance of the waterways is funded in part by the Inland Waterways Trust Fund (IWTF). The fund is designed to finance half the cost of new construction and major rehabilitation. The other half of the financing comes from the federal government through appropriations from its General Fund. The IWTF has several components, chief of which is a fuel tax paid by the carriers. In its report, the IMCT-CSS team recommended an increase of 30 to 45 percent in the current fuel tax of 20 cents per gallon, which translates to increases of 6 to 9 cents per gallon of fuel.

In regard to cost-sharing in the future, the report made the following recommendations:

- All lock construction projects should be cost shared, with 50 percent coming from General Federal appropriations and 50 percent coming from the IWTF. Lock rehabilitation projects that exceed \$100 million should be similarly cost shared.
- Construction and major rehabilitation of dam projects and lock rehabilitation projects costing less than \$100 million would be funded from general appropriations.

These two provisions would result in a funding system with the following breakdown: the IWTF would provide \$110 million each year and the federal government would appropriate \$270 million.

The Role of the States

Despite the federal government's exclusive responsibility for dredging channels and for upgrading and maintaining lock and dam infrastructure, the states that have commercially navigable rivers running through (or adjacent to) their borders also play an active role in shaping the operation of the inland waterways system. They have developed a variety of mechanisms to support and encourage waterway transportation and waterborne commerce. Openly viewing inland waterways as vital for maintaining the health of all industries that depend on the river for transportation, many states have created port authorities to invest in port infrastructure.

The financing of river ports varies from state-funded-and-owned ports to locally funded public port authorities that merely rent port facilities. Regardless of the financing mechanism, port facilitates establish intermodal terminals that serve as interfaces between waterborne commerce and landside transport. In this respect, they enhance the overall efficiency of the nation's transportation system, as rail and trucking facilities benefit from connection to port facilities.

States also support inland waterway transportation infrastructure upgrades by working with multistate stakeholder coalitions to influence federal funding for USACE lock and dam infrastructure improvements. Multistate stakeholder groups include the Ohio River Basin Alliance, the

Ohio River Valley Water Sanitation Commission (ORSANCO), and the Ohio River Basin Congressional Caucus.

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See Also: Canals and Locks; Inland Waterways, Freight Traffic and; Inland Waterways, Navigation of; Inland Waterways, Traffic Management and.

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Inland Waterways, Traffic Management and

Globalization has made traffic management on inland waterways around the world more politically and economically essential, and it has challenged local, state, and national authorities from Tampa Bay, Florida, to Singapore. Inland water transport creates environmentally friendly, cheap, and efficient transportation, but it also requires effective traffic management. The increase or decrease—depending on

location—in size and volume of vessel traffic combined with the physical characteristics of the waterway, rapidly changing weather patterns, political and economic fluctuations, development of infrastructure, and the entity managing the waterway requires traffic managers to continually organize and resolve vessel traffic situations.

According to Hans van der Werf, secretary general of the Central Commission for the Navigation of the Rhine, the challenges in inland water transport faced in Europe, North America, and Asia are all the same. He believes that some of the localized navigational problems like those involving vessel types and cargos can be solved with universal solutions.

Vessel Type and Traffic Fluctuations

Maritime traffic in both Europe and the United States must deal with vessel traffic fluctuations moving with political and economic conditions, making managing inland waterways difficult. In 2012, among the top five ports in Europe, Antwerp and Amsterdam in the Netherlands reported increases compared with the fourth quarter of 2011, while Hamburg, Germany, and Marseille, France, recorded decreases. Europe's inland waterway system is operating under difficult economic circumstances, with 80 percent of the fleet operated by owner-operators, making it difficult to match supply with demand and hampering the sector's ability to reinvest and innovate. Employment in the sector is estimated to have decreased 10 percent. The aging employee population, with 50 percent of the workers over 50 years old, is another management problem. The rapid growth of freight logistics markets and an already congested land-based infrastructure also makes innovation of vessels necessary.

Partial Air-Cushion Supported Catamaran

Partially developed with funding from the European Union, the Partial Air-Cushion Supported Catamaran (PACSCAT) is projected to be one of the vessel types of the future. The PACSCAT is a high-speed, low-wash, variable draught vessel designed to operate on the Rhine and Danube Rivers. Moving at a speed of around 23 mph (37 km/hr), the ship can make the more than 1,000-mile trip from Constanza, Romania, to Passau, Germany, in three days compared to the current voyage time of seven days by barge, which makes it compete on an equal basis

with road transportation. The PACSCAT's average speed of 22 to 24 knots can be increased to 40 knots in open water, such as on the Great Lakes under the right conditions.

The PACSCAT can carry 2,000 tons, which approximates about 45 truckloads, and its draught can be adjusted from 8 feet to as low as 5 feet to meet shallow conditions; air draught can be changed to allow for bridge height limitations. The air cushion is encased between the side hulls and end seals and installed lift fans generate it to reduce the propulsion power requirements—important features in waterway navigation. The PACSCAT is designed to use existing berthing or loading facilities. Designers say that PACSCAT features can be applicable to short sea operations, possibly with a river transit as part of the route to avoid unnecessary transshipment of cargo.

Container Ships

Incremental improvements in container ship design have transformed container ships from 10- to 15-knot vessels to 22- to 23-knot vessels, which compares favorably with the PACSCAT river vessels, which achieve 22 to 24 knots. Modern container ships can carry between 400 and 1,400 20-foot equivalent unit (TEU) containers, the standard freight carrying measurement for container ships. Container ships have a draft of approximately 2 feet, which can adapt to some navigational systems like the St. Lawrence Seaway, but the new Triple-E class container ships (the E representing economy of scale, energy efficiency, and environmentally improved) have presented costly and time-consuming problems for ports. Almost a quarter-mile long and taller than a 20-story building, the Triple Es can move goods more cheaply and efficiently than current ships, but they are too big for most of the world's ports.

Only a few European ports, including Southampton in the United Kingdom (UK), can handle the Triple-E container ships, and in 2013, no port in North America could handle them. They cannot fit into the Panama Canal locks and can just squeeze through the Suez Canal, so they will only travel the China-to-Europe route, bringing in goods and making the return voyage mostly empty except for cargos of scrap metal and plastic waste for recycling.

Shanghai is the leading container port in mainland China, with a 2005 total of 18.08 million TEU.



A barge on China's Grand Canal (the Hangzhou–Beijing waterway) in 2008. The Grand Canal is the longest human-made waterway in the world at 1,083 miles (1,743 kilometers). China's overall inland waterway network, also the largest in the world, has a navigable length of 76,736 miles (123,495 kilometers) and consists of over 5,000 rivers and tributaries.

The Shanghai Port Authority has converted general cargo terminals into container terminals and is constructing a new port at Yangshan Island south of Shanghai with 52 berths and a capacity of 20 million TEU, to be fully operational by 2020.

Tugboat Barges

Tug/barge vessels transport freight on many North American and European inland waterways, a practice that evolved on the Rhine–Danube River system to move containers and bulk cargo by making barge rates competitive with rail and truck. The German prohibition of trucks on German roads during weekends significantly improved barge competitiveness. Scheduled movements, current information systems, and the ability to provide a wide range of cargo-carrying options make tugboat barges a useful management option.

Tugboat barges are also important factors in Asian and African waterway maritime transportation systems. More than 80 percent of China's cargo

traffic travels on the Yangtze River and much of that on tugboat barges. Weak or nonexistent infrastructure, lack of current charts, and the Yangtze's bends and rapids are just a few Yangtze traffic management challenges.

The Amazon River system is the longest continuous navigable waterway in the world, with oceangoing vessels navigating as far 2,300 miles upriver, as far as Iquitos, Peru, with only shallow draft barges able to navigate the Amazon upstream south of Iquitos. Even though the Amazon is the primary river system in South America, it took until the 21st century for the Peruvian navy to complete a hydrological map of the Amazon and create electronic maps allowing draft tugs and barges to transport construction materials upriver to the natural gas fields on the eastern flanks of the Andes Mountains. A communications network for barges and tugs, a series of accurate charts, and modern ports are management tools important for future Amazon development.

Ferry Boats

The high-speed technology of the late 20th century and early 21st century increasing the speed of ferry services to 30 to 40 knots instead of the 15 to 20 knots of conventional ferries has revolutionized the nature of ferry operations around the world. The Stena Line, the biggest ferry operator in Europe, offers a large fleet and a wide selection of routes and destinations, including ferries in Ireland, Britain, and Holland. Stena Lines introduced the HSS 1500 between Dun Laoghaire in southern Ireland to Holyhead in Wales, a 70-mile route across the St. Georges Channel through some of the roughest waters around Britain. The new high-speed ferry reduced the voyage to two hours instead of the four-hour service in place when the route used conventional ferries. This speed change allowed Stena Lines to use one vessel instead of two for significant economic saving. The HSS 1500 can carry 350 TEU as well as 1,500 passengers.

The management issues with the HSS 1500 are concerns about its width, which at 131 feet would make it too wide for the Great Lakes St. Lawrence Seaway System locks, and its wake, which might be too powerful for river and canal operation. The European Union has been working to develop high-speed ferry technology for river work, especially for the Rhine and Danube Rivers.

U.S. Maritime Traffic Management

The U.S. inland and intracoastal waterway system is not as well-known as its airways and airports or railway or highway networks, but inland waterways are an essential and often overlooked part of America's freight transportation system, handling approximately 600 million tons and 300 billion ton-miles of domestic cargo shipments a year. Inland waterways are the primary artery for more than half of the nation's grain and oilseed exports, for about 20 percent of the coal for utility plants, and for about 22 percent of domestic petroleum. Most of the cargo is raw materials and liquid and bulk cargo like coal, petroleum, chemicals, grain, processed metals, food, farm products, and cement, sand, and gravel. The U.S. Army Corps of Engineers (USACE) has overseen and maintained the waterways since the 19th century, but in the 21st century, politics and special interest groups as well as economic pressures have affected the overseeing and modernization of the inland waterways.

Commercial towboats pushing barges lashed together as tows make up the majority of the inland waterway traffic. Each barge has a capacity of 1,400 to 1,800 tons of cargo and a single 15-barge tow carries the freight car equivalent of 870 tractor trailer trucks, creating an inexpensive and fuel-efficient method of freight hauling especially suited to bulk cargo that is not time sensitive.

In the United States, a system of 192 commercially active lock sites with 28 lock chambers provides navigation channels on nearly 12,000 miles of inland and intracoastal waterways. The USACE manages the system as part of its civil works program, and according to the USACE, the system is in peril. The infrastructure supporting this inland waterway system is aging, and a major failure of locks and dams could incapacitate the entire system. Age, time, and lack of maintenance are wearing down the reliability and capacity of the structure of inland waterways.

To complicate the situation, demand for freight transportation in America is escalating. The U.S. Department of Transportation's "Freight Analysis Framework" report forecasts a 70 percent increase in freight traffic by 2020. Traffic on inland waterways is forecast to increase by 51 million tons of freight from 2012 to 2020, and by 2040, the increase is expected to exceed 118 million tons. This growth will challenge the capabilities of the transportation systems, especially highways, but it will also impact rail and water transportation.

The marine ports system is especially important for America's international trade, valued at more than \$944 billion in imports arriving in the United States by water. America depends heavily on waterborne trade for its growing export markets, especially agricultural products, manufactured goods, and the exporting of energy and refined petroleum products. Even if growth slows worldwide and Europe continues to undergo economic problems, trade with Asia and Latin America and growth forecasts require major investments in U.S. marine ports.

Managing the St. Lawrence Seaway

According to a study of the St. Lawrence Seaway, a 2,300-mile inland waterway connecting the Great Lakes to the Atlantic Ocean, maritime traffic systems in the United States and especially along the St. Lawrence Seaway need a major overhaul to remain competitive in the global maritime system.

The study report, prepared for the U.S. Department of Transportation/Transport Canada and titled “Great Lakes-St. Lawrence Seaway New Cargos/New Vessels Market Assessment Report,” looked especially at cargos that have unique characteristics that make them susceptible to transportation management restrictions, including hazardous materials and cargo needing refrigeration, which subject them to increased handling costs and transportation restrictions. Maritime management might ban hazardous materials from critical bridges and tunnels, and cargo needing refrigeration has to be stored and moved in a timely manner.

System capacity is becoming an increasingly important factor in future shipping decisions, because planners anticipate that supply side limitations including labor—mostly the trucking industry—and infrastructure will make current distribution systems less cost effective and limit what they can carry. Cargo capacities of containers, vessels, and ports need to be carefully considered and factored into traffic management planning.

Managing the Upper Mississippi Inland Waterway

The U.S. Department of Transportation sponsored a 2005 study of traffic management on the Upper Mississippi River (UMR), which scrutinized traffic management on the river system. The study recommended that new traffic management policies including appointment and scheduling systems for vessel traffic not be implemented on the UMR because they would cost too much and create too many disruptions in the water transportation markets. The study stressed that evaluating new traffic management policies like appointment and scheduling systems should take place to determine the effectiveness of alternative management policies, as traffic levels have significantly increased and locks have degraded. The study recommended that vessel tracking systems for lockage or traffic management on the UMR should be designed to coincide with management alternatives, and that responsibility and legal authority for UMR lockage and traffic management should be clarified before implementing new and far-reaching lockage and traffic management systems. The study also said that traffic management policymakers should explore opportunities to partner with other agencies and private organizations to develop vessel tracking on the

UMR and strengthen the alliance with the Coast Guard in implementing vessel tracking systems.

Managing the Intracoastal Waterway

Extending for about 3,000 miles along the Atlantic Ocean and the Gulf of Mexico coasts in the southern and eastern United States, and spanning the five Gulf Coast states, the Intracoastal Waterway (ICW) is vital to the American economy, carrying one-third of the freight of all U.S. waterways. The USACE maintains the ICW, which is connected to sounds, bays, lagoons, rivers, and canals in many places and deep-draft vessels can navigate some portions of it. Protecting, maintaining, and improving the ICW ensures the future of many people and businesses depending on the efficiency and economy of barges and other vessels transporting cargo.

The USACE faces management challenges from environmentalists objecting to what they consider excessive dredging of some portions of the waterway and filling other portions of the waterway with what they consider unsafe materials.

Colorado River Locks

The Colorado River Locks provide a navigable waterway for towboat and other marine traffic while preventing the waters of the Colorado River from flowing into the Gulf Intracoastal Waterway where they intersect. The Galveston District USACE designed and built the Colorado River Locks in 1954 to allow vessels and barges to pass during high water in the Colorado River. During normal Colorado River conditions, they use the locks as floodgates to prevent silting in the ICW. The USACE maintains the locks and lock keepers are employed to assist vessels in their passage through the locks. Now nearly six decades old, the locks need constant maintenance and will eventually have to be replaced.

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See Also: Canals and Locks; Harbor and Port Planning; Inland Waterways, Freight Traffic and; Inland Waterways, Navigation of; Inland Waterways, Planning and; Maritime Transport.

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Institute of Traffic Engineers

In 1930, in response to the needs of the rapidly changing transportation sector, transportation officials interested in the emerging field of traffic engineering came together to establish the Institution

of Traffic Engineers (ITE). In 1975, the name of the organization was changed to the Institute of Transportation Engineers. ITE's membership of approximately 17,000 individuals and organizations in more than 90 countries includes not only traffic engineers but also a wide range of transportation professionals from the fields of transportation planning, consulting, education, and research. Belying its global membership roster, the major portion of the group's work is focused in the United States. In addition to the national headquarters, which is located in Washington, D.C., there are various regional and state ITE agencies that carry out the work of the organization.

As an organization that focuses on ground transportation, the mission of ITE is to assist transportation professionals in fulfilling the mobility and safety needs of states, regions, and nations. These goals are accomplished by applying technology and scientific principles to all fields of transportation. These fields encompass research, planning, functional design, implementation, operation, policy development, and management. ITE projects and activities include providing member support, encouraging education, stimulating research, developing public awareness, and promoting the exchange of information relevant to members of the transportation engineering sector.

A number of meetings and seminars are held throughout the year to facilitate the exchange of relevant information. These meetings deal with subjects such as planning, engineering and design, safety, mobility and operations, and implementing transportation solutions. By participating in professional development sessions during annual conferences, attendees earn credits in transportation engineering as approved by the International Association of Continuing Education and Training. Exhibits are always popular at ITE conferences, and they provide a channel for demonstrating new technologies and products. The *ITE Journal* is published monthly to further the goal of facilitating the exchange of information in the field. Throughout its history, the organization has also published a large number of handbooks and manuals for use by individuals within the field of transportation engineering. The success of the Internet has provided an additional avenue for exchanging information, and ITE's Web site enables access to an online bookstore that offers materials of interest to members of the transportation engineering community.

ITE recognizes excellence in the transportation engineering field by awarding the distinction of "ITE Fellow" to a limited number of individuals. The requirements for achieving this distinction are being a registered engineer, having demonstrated success at taking on responsibility for significant work in the field of transportation or traffic engineering, and contributing to the work of ITE or to the field of traffic engineering.

History

In the years following the end of World War I, the ever-increasing number of automobiles on American roads led to mounting traffic problems. In large cities, the addition of buses and streetcar tracks that frequently ran down the center of city streets made it even more difficult for automobiles to proceed safely and efficiently. The result was an increased number of traffic-related accidents in U.S. cities. These combined factors led to considerable pressure being placed on politicians to deal with problems that were beyond their individual abilities to handle. In turn, politicians turned to civil and electrical engineers for solutions in designing devices to regulate the flow of traffic.

Because no programs existed for training engineers to become experts in traffic engineering, they were forced to train themselves to deal with issues that arose in ground transportation, often learning by trial and error. While frustrating for engineers, this method of learning the field had the advantage of encouraging innovation. One such innovator was Charles Adler, Jr. (1899–1980). As an engineer who was also an inventor, Adler created the first traffic signal, a pedestrian push-button device that was installed at Falls Road and Belvedere Avenue in Baltimore, Maryland, in 1928. Some engineers chose to focus on designing roads with the goal of making them safer and more efficient. Because the field of traffic engineering was still so new, transportation engineers frequently sought advice from one another, and they tended to cluster together at the meetings of other professional groups.

Out of recognition of the need for both licensing and training, the idea of a professional organization for transportation engineers was born. On October 2, 1930, while attending the annual meeting of the National Safety Council in Pittsburgh, Pennsylvania, 30 transportation officials established the Institute of Traffic Engineers. The stated mission

of the new group was to provide a channel for the exchange of information, promote professionalism within the field, and encourage local and state governments to create transportation engineering departments to deal with safety and mobility issues on an ongoing basis. During the planning stages, there was considerable discussion about whether the group should be an organization for all individuals involved in the field or only for those with professional standing. The decision was ultimately made to establish the Institute of Traffic Engineers as a professional organization.

ITE's constitution and bylaws were approved at a subsequent meeting in New York City on January 20, 1931. The first president of the organization was Ernest P. Goodrich (1874–1955), a civil engineer who had been educated at the University of Michigan. After leaving office in 1932, Goodrich continued to be active in his field. He worked with the U.S. Navy and the New York City Departments of Public Works and Sanitation. He also worked abroad, participating in city planning in Nanking and Whampoa in China and in port facility planning in Bogotá, Colombia.

The role of ITE was strengthened during World War II, and the organization grew significantly in the postwar years. Creating regional and state divisions in the 1950s allowed the ITE to become more closely involved in promoting safety and mobility at lower levels and encouraged cohesion among experts in the field of traffic engineering. In 1975 the Institute of Traffic Engineers became the Institute of Transportation Engineers in order to more accurately reflect its membership.

Organization

Within the Institute of Transportation Engineers, approximately 11,000 members participate in the work of 12 special-interest councils. Each council publishes its own newsletter in order to keep members informed about new research, relevant issues, emerging trends, and proposed legislation. An international board of direction offers guidance to the various councils. Technical councils include Freight Mobility, Management and Operations/ITS, Parking, Traffic Engineering, Transit, Transportation Expert Witness, and Transportation Safety. Employer-based councils include Public Agency, Transportation Consultants, and Transportation Education.

ITE in Action

One of the ongoing responsibilities of ITE is to serve as the voice of the people by monitoring the efficiency of traffic-control devices. In 2005, for instance, ITE reported that many Americans were up in arms over the inefficiency of traffic lights that caused them to wait in traffic jams for extended periods, wasting gasoline and contributing to the air pollution caused by burning fossil fuels.

As reported by *USA Today*, ITE officials stated that of the 378 traffic agencies located in 49 U.S. states, two-thirds failed to engage in ongoing monitoring of traffic lights. ITE also contended that these traffic agencies failed to respond to problems as they arose. ITE expressed concern that a 2004 study conducted by Philip Tarnoff of the University of Maryland's Center for Advanced Transportation Technology had revealed that most states had not reset their traffic lights at all during the previous decade, despite major social and economic changes.

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See Also: Highway Design and Engineering; Traffic Control Devices; Traffic Engineering; Transit Planning, International; Transportation Planning.

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Integrated Transportation and Urban Land Use Planning Models

A transportation and land-use feedback cycle introduced by Michael Wegener and Franz Fuerst summarized that a transportation system creates spatial accessibility and that spatial accessibility influences location decisions for the land-use system. The land-use system—residential, industrial, or commercial—in turn affects the locations of human activities such as living, working, shopping, education, or leisure. These human activities form trip patterns in the transportation system. Because of this cyclic relationship between transportation and land use, several integrated models have been developed in the past few decades, including the original Lowry model, the Garin-Lowry model, the Integrated Transportation And Land-Use Model Package (ITLUP), the Projective Optimization Land Use Information System (POLIS), MEPLAN, Kim's Chicago model, and URBANSIM.

ITLUP is a Lowry-type model that combines two separate components: a land use model and a transportation network model. POLIS is a mathematical programming-based model formulated as a nonlinear mathematical programming in which locations of jobs and housing, and travel patterns are modeled simultaneously. MEPLAN is based on spatial input-output analysis developed by Marcial Echenique and Partners Ltd. in the United Kingdom. Kim's Chicago model employs an urban economics concept that integrates general system equilibrium with probabilistic spatial interactions, combines transportation-facility location models, and equilibrates demand and supply over networks. URBANSIM is a microsimulation model incorporating the interactions between land use, transportation, and public policy. This article focuses only on the two major and widely used integrated models namely Lowry (the original and Garin-Lowry) and URBANSIM models.

The purpose of land use-transportation models is multidimensional. The models estimate demands for employment, residential, commercial and other activities and integrate the demand with

transportation needs and supply. The models also help gain a better understanding of the urban areas for which transportation planning is necessary. Land use and transportation planning ideologies have changed from ideas of the 1950s and 1960s to the ideas of the 21st century. These planning ideologies were captured in different models that integrate transportation and land use.

Some of the past ideologies like the Lowry-type model called for planning to take into consideration the growth in urban areas and the values such growth would add to the labor force and retail sectors. In addition, since this model concentrated heavily on the growth of urban areas in terms of the increase in population and jobs, it did not take much into account the added need for multiple modes of transportation. However, a more current integration of transportation and land use planning models such as URBANSIM takes into account many more variables than the traditional ones, such as population, employment, and housing. With the URBANSIM model, users can account for other variables that are important in the 21st century, such as greenhouse gas emissions, environmentally sensitive habitats, and protection of open spaces.

Lowry-Type Model

The Lowry-type model was developed in 1964 by Ira Lowry for the metro area of Pittsburgh, Pennsylvania. The model represents well the relationships between transportation and land use. The model is a computer microsimulation model used to understand the spatial organization of human activities, taking into account public decisions (for example, urban renewal, tax policies, land use controls, and transportation investment). The core assumption of the Lowry model is that regional and urban growth (or decline) is a function of the expansion (or contraction) of the basic sector. This sector in turn has impacts on the employment of two other sectors, retail and residential. The model can account for variables such as employment and population by sectors in a region. The Lowry-type model focuses on the impact of urban growth and employment change on retail and residential areas. The model determines the retail and residential potentials based on labor force. The Lowry model considers three economic groupings: the basic sector, the retail sector, and household sector. The basic sector, or site-oriented as suggested by him, is where

all business, industrial, and administrative work taking place serves nonlocal residents. Next is the retail sector, which contains the same type businesses mentioned above but these businesses serve locals and the needs of the local employment force. Last of the three sectors is the household sector. This sector is one where there are high household populations, and the labor force in this area is correlated to the size of the population. In short, the model sums up the activities in a region into zones of 1 square mile, taking into account the amount of employment and site space occupied by each establishment. The model also accounts for the constraints created by buildings and zoning laws.

Studies have suggested that the Lowry model has some limitations; the major shortcoming of the model is that it is a static model, meaning it does not tell anything about the evolution of the transportation/land use system. Current economic changes are in the service (nonbasic) sectors, forming the foundation of urban productivity and dynamics in many metropolitan areas. Under such circumstances the model is likely to be inaccurate in the major service-oriented metropolitan areas of the 21st century. A way to overcome this issue is to consider some nonbasic service employment as basic. Also, the Lowry model does not consider movements of freight in urban areas, which are very significant and have impacts on the friction of distance.

The Garin–Lowry model incorporates interaction submodels that distribute all activities at every iteration of the calculation. A reformulation by Garin improved the original Lowry model in several ways. As summarized by Joseph Berechman and Kenneth Small, the entire Garin–Lowry model is in matrix notation, which simplifies the presentation of the model and exposes the underlying equilibrium inherent in the iterative solution procedure. The input data include zonal levels of basic employment, inter-zonal travel cost matrices for home-to-work and home-to-shopping trips, zonal levels of attractiveness for residential and service locations, and control parameters for the economic-based mechanism. Based on these inputs, the workers in the basic employment sector are allocated to residential zones. The incremental residential population and the resulting incremental dependent service employment are then calculated. This increment of employment is distributed to workplace

zones, and the corresponding increment in population is then derived and distributed spatially to residential zones. At each iteration, a check is made to ascertain that zonal densities of service and residential population are within preset bounds. If they are not, an iterative procedure is applied to reallocate the latest increments by changing the zonal attraction parameters. The Garin–Lowry model has been used successfully to replicate observed spatial distributions of land use activities and to analyze the impacts of major changes. The model has a simple structure and a spatial-allocation mechanism that mimics the randomness in the decisions of individuals.

URBANSIM Model

The origin of URBANSIM came from collaborate efforts by the Oregon Department of Transportation's Transportation and Land Use Model Integration Project (TLUMIP), the State of Utah's Quality Growth Enhancement Tool (UQGET), Envision Utah efforts, and the Oahu Metropolitan Planning Organization's investment in new land use and transportation planning models. According to the creator, Paul Waddell, in 1996 the TLUMIP initiated two models; first was the TRANUS model and second was the development of the URBANSIM model. Furthermore, TLUMIP use of the URBANSIM model extended to other planning regions of the United States, such as Honolulu, Hawai'i, and a prototype has been used in the Eugene–Springfield (Oregon) Metropolitan Area; testing data from 1980 to 1994 has given a verifiable justification of the model. Recent surveys show that URBANSIM has become the most widely used land use model system by planning agencies in the United States.

URBANSIM is a software-based simulation system for supporting planning and analysis of urban development, incorporating the interactions among land use, transportation, the economy, and the environment. URBANSIM is a collaboration by many planners and meant for the use of metropolitan planning organizations (MPOs), municipalities, cities, students, and researchers in order to investigate the effects on planning when multiple parameters, such as infrastructure, policy, accessibility, housing, habitats, and greenhouse gases, are taken into account. URBANSIM encompasses several theoretical models, such as random utility theory, urban economics/bid rent theory, hedonic price

theory, dynamic market equilibrium, microsimulation, and geographic information systems and spatial analysis.

More importantly, the URBANSIM model takes into account many factors in development, such as urban land, housing, nonresidential space, and transportation. By taking into account the developments and connections between government decisions and urban growth, URBANSIM maximizes its effectiveness in assessing the impacts and better influences planning decisions. Therefore, the model enhances the strategic planning capabilities of MPOs and other state and local agencies needing to evaluate growth management policies such as urban growth boundaries, assess consistency of land use and transportation plans, and address conformity with respect to air quality implementation plans. The URBANSIM model, as indicated in the work of Billy Charlton, is one that requires lots of input information, such as population and employment estimates, regional economic forecasts, transportation systems, and land use plans, land development policies such as density constraints, environmental constraints, and development impact fees. Once such information has been input into the URBANSIM system, it will come up with several alternatives and forecast scenarios. These scenarios can then be enhanced to meet the specific purpose of a project and compared to decide on a best alternative.

URBANSIM is great at separating its input component parts, such as households, business, and land use, and allocating importance to those that are chosen by the user and the available data. Once constructed to the specifications of the user, the output data can include future-year distributions of population, households by type (for example, income, age of household head, household size, presence of children, and housing type), businesses by type (for example, industry and number of employees), land use by type (user specified), units of housing by type, square footage of nonresidential space by type, densities of development by type of land use, prices of land, and improvements by land use. The output also includes transportation data such as accessibility, mode shares, vehicle miles traveled, congestion delay, etc.

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See Also: Microsimulation Models; Transportation Impacts on Land Use; Transportation Planning.

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that transportation planners face. These challenges now extend beyond unimodal planning to a more multimodal approach trying to improve interfaces across modes.

Background

The first ITS applications have their roots in engineers' early attempts to find more "intelligent" and effective ways to control road traffic. The first traffic signal control systems could be considered the first ITS systems. Since then, applications have been developed throughout the world, covering road traffic management and all other transportation modes' needs and making use of various technologies, as well as benefiting the transport industry and the public by providing effective and reliable traffic management and travel information provisioning schemes.

Besides infrastructure, ITS are now considered the most important factor that can effect cooperation among various transport modes to create a seamless transportation system across Europe. Important stakeholder communities (ERTICO, ITS-America, ITS-Japan, ITS-Germany, etc.) are providing or utilizing ITS applications and services and contributing to economic and social development.

Many countries have already created specific legislation related to the deployment of ITS. In the early 2000s, apart from national legislation, there was an effort to gradually put in place a legal framework at both a transnational (Europe, United States) and international level. Such efforts concluded with directives for the deployment of ITS, which sets the foundation for further legislative integration on behalf of the involved countries.

Technologies and Role

ITS applications make use of "telematics." The word *telematics* derives from the Greek words *tele* meaning "from a distance" and *matos* meaning "of its own accord." In recent years, telematics have been introduced to a significant portion of the transportation sector for both urban and intercity transport services. The use of telematics in ITS is provided through a variety of information and communication technologies. Regarding communications, ITS make use of Internet communications (online payment, routing based on real-time traffic information), mobile communications (travel information provision, routing based on real-time information) and various wave-transmitting communications

Intelligent Transportation Systems

Intelligent transportation systems (ITS) refer to all information and communication technologies (ICT) that are used in the transport sector, including in any kind of transport infrastructure and in any type of vehicle. The term *ITS* is defined as the applications of advanced technologies using computing systems, communications, appropriate infrastructure, and other electronic and non-electronic devices for the provision of more effective traffic and mobility management as well as a better level of transport services for travelers. ITS implementation is one of the cornerstones of modern transportation engineering as it provides great potential for tackling most of the challenges

(Bluetooth technology, microwaves). Geographical tracking position technologies are also included in the communications category, which includes automatic vehicle location systems (AVL) and the Global Positioning System (GPS). The information category includes traffic data collection technologies such as closed-circuit television (CCTV) cameras and sensor loops, as well as various software related to the statistical analysis of data, traffic assignment, routing algorithms, and more.

Traffic and Travel Information

Traffic and travel information (TTI) systems aim to provide information to travelers regarding their trip. Recent technologies make use of real-time data and provide online information regarding dynamic aspects of transportation (level of traffic congestion in urban areas, travel time, etc.).

TTIs are highly related to optimal use of traffic and travel data, including collection, processing, and final transmission. The main issues that transport planners have to deal with in the deployment of this type of ITS are the technical standards used and their interoperability, the legal framework and possible business models for TTI provision, and the extent to which travelers are reacting to the provided information.

Traffic and Public Transport Management

This category of ITS aims to improve traffic management in urban and interurban transport networks. It focuses not only on road transport but also on interfaces between road transport and other transport modes. Typical applications in this category are the intelligent traffic signal control systems, the incident detection and management systems, the systems providing priority to specific types of vehicles such as emergency response vehicles, the intelligent lane control systems, speed limit enforcement, longer distance diversions and rerouting, and floating car data collection systems.

All these applications have been used in previous decades for improving traffic conditions in traffic-burdened areas, at the same time increasing user safety and travel comfort. Research in this ITS field in regard to road traffic management has led to the development of traffic management tools and applications that many transport authorities in urban areas use in an integrated way through mobility management centers and traffic control centers.

Navigation Services

The introduction of satellite navigation technologies has enabled the development of navigation systems and services that include technologies related to identifying the position of a vehicle or load unit (positioning) and providing instructions for the optimal route to one's destination. GPS data is used for tracking vehicles and providing accurate positioning.

Vehicle tracking is mainly used in the freight transport industry to improve monitoring and securing cargo. Passenger transport ITS navigation systems couple navigation services with real-time traffic data in order to provide route guidance based on real-time traffic conditions.

ITS navigation services mainly use communication technologies and mobile cellular networks. The 3G communications protocol and the spread of wireless Internet technologies have contributed to the possibilities for exchanging larger amounts of traffic-related data, in real or near real time, at affordable costs.

Smart Ticketing and Pricing

ITS technologies provide services for the collection of fees (mainly tolls) both in intercity and urban pricing systems. In recent years, new technologies have enabled the upgrade of pricing policies, making it possible to introduce various fares in one specific system based on specific and socially fairer criteria (vehicle's emissions, level of noise produced, etc.). A specific area within this category is the "smart ticketing" systems, which refer to a more precise pricing of public transport based on the degree of usage of each mode and, at the same time, provision of various payment options and other services.

Through this type of ITS application, interoperability between various transport modes can be more effective in providing a fully multimodal transport network, especially in urban public transport systems. ITS applications that assist smart ticketing and pricing in the field of transport, especially in the road sector, will likely be commonplace in future urban and interurban networks.

Safety and Security

Safety and security are the most important factors in transport policies. A safety-oriented ITS system needs to provide real-time information

that will help drivers avoid a crash or mitigate the consequences of a crash. The ITS technologies in this category include “autonomous” solutions (for example, systems that concern only the infrastructure or are in-vehicle based), and “cooperative” solutions (employing vehicle-to-vehicle or infrastructure-to-vehicle communication of information and data). Furthermore, these applications could be categorized as “passive” or “active” safety systems according to whether they are (passively) preventing and protecting drivers and passengers in case of an accident, or (proactively) assisting the driver to achieve the desired level of safety.

Freight Transport and Logistics

ITS for freight transport and logistics are realized through a set of “intelligent” services such as application programs and technologies for gathering, storing, analyzing, and providing access to cargo data to help users make better decisions. ITS contribute to improving the efficiency of freight transport by developing interoperable information services at national and global levels and building on standardized data structures (for example, the DATEX II) and exchange services.

Intelligent Mobility and Co-Modality Services

Mobility management refers to the effective handling of the transport demand for a particular area. All previously mentioned categories can contribute to the promotion of intelligent mobility management as well as to the co-modality (cooperation between the modes).

Environmental and Energy Efficiency

The main objectives of ITS for energy efficiency are to help provide cleaner, more energy efficient, and safer transport. Most of the previously discussed categories can be included in this category as they can positively influence the environmental and energy efficiency of transport systems. However, there are some specific applications that are most directly relevant, such as environmental route guidance (to avoid forecasted congestion), ecodriving (environmentally sensitive driving), and more.

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See Also: Advanced Traveler Information Systems; Automated Traffic Control Systems; Automated Transit Systems; Automated Vehicle Location Systems; Automated Vehicle Monitoring Systems; Electronic Route Guidance Systems; GPS; GPS, Automobile; ICT, Social Impacts of; Incident Detection Systems, Automobile; Intelligent Vehicle Highway Systems; Intermodal Freight Transport, Technology and; Traffic Detection Systems; Traffic Detection Technology; Traffic Monitoring; Transit Information Systems; Transit System Technology; Trucking, Computer Monitoring Systems and.

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Intelligent Vehicle Highway Systems

The intelligent vehicle highway system (IVHS) represents a smart transportation system that utilizes technology to permit motor vehicles and roadways to communicate with each other via two-way communication devices. IVHS is anticipated to make travel by automobiles and other motor vehicles easier, faster, safer, more efficient, and more reliable by integrating features of travel by private vehicle with those of mass transit systems. In order to achieve this goal, IVHS works to integrate the flow of freight and passengers across transit modes in a manner that is convenient, efficient, and reliable. In designing programs to implement IVHS, special

care is taken to present solutions to bottlenecks that otherwise bedevil those using rail, roads, sky, sea, and waterways. With considerable support from the U.S. Department of Transportation (USDOT), IVHS will continue to evolve to provide safer and faster travel options for many.

Background

As technology has evolved, many policy makers and researchers have investigated smart transportation systems as a way to speed commutes, reduce fatalities, and reduce energy consumption. To that end, many corporations, universities, government agencies, and others have worked to make IVHS a reality. IVHS entails a series of automated highways that include a set of lanes that use specialized sensors and wireless communications systems that permit automobiles to travel under computer control at safely spaced intervals. To assist with this, IVHS explores how real-time traffic data can be collected and transmitted to the public in real time by means of dynamic message signs, instant messaging, and other means. This real-time traffic data can also be used to regulate ramp meters that improve the flow of traffic on highways and to synchronize traffic lights so that their times are adjusted in response to traffic patterns. To coordinate and fund these innovations, the USDOT created IVHS and has funded it through its Research and Innovative Technology Administration (RITA).

Development

RITA was founded in 2005 and serves as a unit of the USDOT. Initiated as part of the Norman Y. Mineta Research and Special Program Improvement Act, RITA is charged with advancing transportation analysis, science, and technology. RITA works to improve the coordination and dissemination of research related to these topics throughout the USDOT and throughout various corporations, agencies, and universities that are interested in developing new innovations related to transportation. With over 750 employees located throughout the United States, RITA concentrates on four areas of research development. First, RITA coordinates the USDOT's research and education programs, ensuring that interested parties are aware of innovative developments. Second, RITA shares advanced technologies that permit innovations within the transportation system. Third, industry

and researchers are provided with analytical, statistical, and other support to facilitate decision making related to transportation. Finally, RITA supports national efforts to disseminate information and provide training in transportation-related fields through funding and other encouragement. All of these efforts help support IVHS, which has been supported by the USDOT in earlier efforts since 1991.

RITA has funded IVHS as a means of improving what is known about how communications and information technology can enhance surface mobility and transportation safety. IVHS is also seen as an engine of economic development that can be used to support economic growth in the United States. The IVHS program has two areas of focus: the development of applications that focus upon the vehicle and the highway infrastructure, as well as applications that facilitate integration of the two. More recently, the focus of RITA has concentrated upon major initiatives, sometimes termed "targets for opportunity," that potentially have the chance to transform mobility, productivity, and safety. For this reason, investment in intelligent vehicles, intelligent infrastructure, and incorporating technological advances into the national transportation system have taken priority. Connected vehicle research has produced some of the most significant developments, as this technology can enhance safety, improve mobility, and benefit the environment. Connected vehicle technology (CVT) uses wireless communication devices to allow vehicles to communicate with other vehicles, the roadway infrastructure, and other sources of information. As these technologies have become more popular, they have become more common. Examples of CVT include geographic information systems (GIS), electronic toll collection, dynamic message signs, and coordinated traffic lights.

Global Positioning System Technology

Although IVHS is often portrayed in the media as a futuristic mode of travel, with smart cars seamlessly entering and exiting traffic with little or no supervision from their human occupants, real-life applications from research into this mode of transit exist today. Over the past decade, for example, Global Positioning System (GPS) data receivers have become a common feature in many motor vehicles. GPS uses a series of satellites that provide navigation



A variable speed limit sign on the Prague Beltway in the Czech Republic in 2010. Variable signs can be quickly modified to suit changing conditions, and dynamic message signs can display more extensive information and warnings about traffic incidents.

data to automobile and other transportation drivers. GPS technology permits information regarding the direction, location, and speed of a targeted vehicle to be shared with GPS transmitter units. This permits the data receiver to calculate directions, detect traffic interruptions, and increase the efficiency and safety of the transportation of people and goods. GPS has greatly assisted freight companies in plotting the navigation and timing of the shipment of goods, as it allows materials to be transported when the roads are least busy and when their conveyance is thus the most efficient and safe. As it has become more common, GPS data has come to be used by a variety of other users, including farmers, meteorologists, and others for a multiplicity of other uses.

Electronic Toll Collection

IVHS has also led to a variety of changes in how roadways are monitored and operated, including

electronic toll collection. Electronic toll collection uses “identification friend or foe” technology, originally developed for the military, to collect tolls electronically, thereby eliminating the delays caused on highways by toll collection. Owners of vehicles have the option to enroll in an electronic toll collection program; those who choose to do so receive a device that includes a transponder, which emits a signal that is detected when the vehicle is driven beneath sensors. A toll is then electronically collected through a debit system, which permits those enrolled in the program to proceed without stopping at a tollbooth. Those not enrolled in the program are directed to a tollbooth to pay in person, slowing their progress. (Those who evade payment by either method are subject to fines and other penalties.)

Many states, including California, Delaware, Florida, Illinois, Pennsylvania, and Texas, have adopted electronic toll collection systems, which have proven highly popular with commuters and other users. Road congestion is significantly reduced by electronic toll collection, as those enrolled in the program do not have to slow down to manually pay a toll. Some municipalities have explored using electronic toll collection as a means of reducing congestion further by charging variable tolls based upon demand, charging a higher toll at times of greatest use.

Signage

Dynamic message signs, sometimes referred to as “variable message signs,” are another innovation supported by IVHS. Dynamic message signs are electronic notices located along roadways that provide travelers with information about special events affecting travel. Warning travelers about accidents, congestion, road work, speed limits, or other incidents, dynamic message signs encourage or require travelers to take alternative routes, thereby improving safety and efficiency of travel. The dynamic message signs may be either permanent parts of the roadway infrastructure or temporary devices deployed for special circumstances. Messages include information about crashes, debris on the roadway, exit ramp closures, road closures, stalls, travel times, vehicle fires, or other data, such as Amber alerts related to missing children. By providing information regarding these events, dynamic message signs can mitigate the duration and impact

of such incidents, thereby improving the performance of the transportation system.

Vehicle Automation

A variety of vehicle automation innovations have also been developed as a result of IVHS. These innovations include autonomous cruise control, adaptive headlights, advanced automatic collision notification, automatic parking, and other devices. Autonomous cruise control automatically adjusts a vehicle's rate of speed so that a car or truck is able to maintain a safe distance from other vehicles. Adaptive headlights change the intensity or range of headlight beams in response to weather conditions, vehicle speed, and road situations.

Advanced automatic collision notification, commercially available from providers such as OnStar, assists emergency medical responders to make determinations regarding the severity of an accident and the treatment needs of the injured by sending crash data to monitors if a vehicle is involved in a severe collision. Automatic parking assists drivers seeking to park their vehicles, using sensors and other controls to steer a car into a parking space with little assistance from the driver. As innovations such as these become more common, IVHS will continue to evolve.

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See Also: Automobile Accident Avoidance Systems; Automated Road-Pricing and Toll-Collection Systems; Automated Traffic Control Systems; Automated Vehicle Location Systems; Automated Vehicle Monitoring Systems; Geographic Information Systems in Transportation; GPS, Automobile; Interstate Highway System; Smart Highways; Traffic Management Systems.

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Interchanges, Modal

An interchange is a facility at a location where it is possible to transfer from one mode of transport to another. At one extreme, an international airport is an interchange, and at the other, the humble bus stop is an interchange between walking and bus transportation. Because no mode of transport can serve every geographic location economically, interchanges are locations where higher level modes (for example, a subway) can collect trips from lower level modes. This requires purpose-built facilities to make the physical transition from one mode of transport to another as safe and easy as possible. In this analysis, higher level modes are those with higher operating speeds and higher passenger capacity. The science of interchange design has advanced as a result of experience and market research feedback.

Location and Distribution

The location of interchange stations, especially park-and-ride stations, is very critical in terms of the site, ease of access, and passenger perception. A number of studies have been undertaken to examine the mathematical relationship between different modes of transport in a network hierarchy. Clearly, the larger the urban area, the more modes of transport that can be supported, and are needed, provided they are arranged to interchange smoothly with each other. This modal relationship is also affected by the relationship of the speed of operation of each mode, and hence the practical minimum distance between adjacent stops on a particular line.

If a city is divided for transit supply purposes into a number of geographic zones, like hexagons, then normally each zone will justify one interchange station. The only other factor will then be the number of lines that serves each interchange and the catchment area served by those lines. If buses are assumed to be the lowest mode in the hierarchy, do bus lines only serve a particular zone, or do they

cross zone boundaries? This is a problem for people living on zone boundaries. If bus lines only operate within a zone, then commuters may have to travel in the opposite direction to reach an interchange station, with a rail line linked to their ultimate destination. For many people this is counterintuitive. Cross-boundary bus services avoid this and also widen the market for transit.

The automobile made interchange station location in some ways easier and in other ways more difficult. If interchanges are located in the wrong place, commuters will drive all the way. So the location of interchanges must be based on a sound understanding of the travel market origin-destination pattern and commuters' perceptions of the ease or difficulty of interchanging. This is in addition to the fare structure and ticketing system, which impacts the utility of interchanges and the perception of the comparative cost of competing journey choices.

Number of Integrated Modes

Even in a city with competing modes of transport, like buses and taxis, it makes good sense for interchange stations to be provided, to enable modal cooperation, improve economic efficiency, and reduce environmental impacts. Sometimes interchanges may be provided by the operator of a higher order mode, (for example, rail) to encourage lower order modes to access and therefore "feed." This will stimulate modal transfer, especially from car trips. Interchanges can also be provided by major facility providers like shopping malls, sports arenas, etc., to improve access to the facility, widen the catchment area, and also as an investment in the urban infrastructure. Finally, interchanges can be provided by the municipality as a civic facility to allow different operators and modes to integrate the local transit network with nontransit modes like car and bicycle.

If the transit system is publicly provided, then the transit authority should be able to plan an optimized hierarchical network with a number of modes, both to expand the catchment area of transit and also to improve transit operational efficiency (supply side) and journey satisfaction (demand side). In a city of about 500,000 people, two transit modes can be integrated with interchange stations. In cities of over 1 million people, three transit modes are practical. The number of

modes, and therefore lines, will determine the number and location of interchanges.

Passenger Acceptance

Commuters do not like changing mode, especially for short journeys. There needs to be a combination of push and pull factors to make interchanging acceptable and attractive. A major push factor is usually widespread road congestion, making auto commuting slow and journey times unpredictable. A pull factor can be a parallel rail line, offering faster trips. In order to tie these together, considerable market research is needed to determine the best place for park-and-ride interchange stations.

From historical evidence of passenger and commuter behavior, interchange stations need to be located close to the origin of trips. A commuter who has to drive three-quarters of the way to the destination will not be tempted to switch to transit for the final quarter of the trip, even if parking at the destination is difficult.

Commuters are concerned with getting to work on time and more relaxed about the return journey home. So the link between the highway and the interchange station needs to be as short and easy as possible for the morning journey. Transit interchanges at highway interchanges are often an excellent solution.

Operating Problems

Most commuter trips are repetitive and planned before the start of the journey. So integrating highway congestion information with transit service information (for example, over the local radio/TV, Twitter or Internet, etc.) will greatly improve the probability of commuters switching and staying with transit via conveniently located interchange stations.

This, however, becomes problematic if the transit service is infrequent or unreliable. The transit operator can address the frequency question by better train and staff scheduling; a handy rule of thumb is that commuters will only use transit if the waiting time at the interchange is shorter than the ride time. There are various ways in which service frequency can be increased with a fixed number of trains (for example, improving operating speed, having a mixture of express and all station trains, etc.).

Improving service reliability is more challenging and requires a thorough understanding of the

causes of unreliability. These may be due to staff shortages, both drivers and maintenance staff, or equipment failures, or track problems. A comprehensive analysis of these causes should lead to a step-by-step program to improve reliability. Letting commuters know that trains are running reliably is another area, and good information at interchange stations is important but service information before leaving home vital.

Finally, the ideal interchange is one where there is a short walk on the level between each mode. Cross-platform bus and rail interchanges are practical, and car parking can be arranged to require the shortest practical walk. All this fails if there is no scheduling cooperation between operators. An incoming bus that just misses the train to downtown will not be an attractive service. Similarly, commuters returning home, seeing the connecting bus depart before the train arrives, will not continue interchanging for long. Operators therefore need to cooperate to ensure that services on different modes are scheduled to accommodate passengers who need to transfer and that they do so.

Multipurpose Sites

People do not naturally like changing modes, but if the utility of the interchange can be increased (for example, by making shopping possible), then there is a synergy to benefit the commuter, transit operator, and additional service provider. So, space at an interchange station can be franchised to a supermarket, a fast food outlet, bank cash machine, etc., allowing passengers to make use of the time interchanging to undertake another domestic requirement. This is especially true on the journey home, where a quick meal, urgent shopping, or getting cash can fill the space between getting off the train and getting back into the car to drive home.

Such multipurpose sites may result from serendipity of market forces or from careful planning and putting together a package attractive to additional service providers. Interchange stations will themselves have a large footfall that will provide a ready-made customer base for additional service providers. This justifies paying a site rent, which helps the transit operator offset some of the costs of building and maintaining the interchange.

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See Also: Mixed-Mode Transit Systems; Transit Centers; Transit Planning.

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Intermodal Freight Transport, Technology and

Intermodal freight transport involves the use of two or more carriage methods to move a shipment under a single freight bill from its point of origin to its final destination via road, rail, waterway, or air.

In the United States, intermodal freight transport is facilitated by both public- and private-sector enterprise. Federal, state, and local government entities typically are responsible for the underlying transportation infrastructure needed for intermodal freight transport, such as airports, roadways, and harbors. Private-sector industry generally manages the execution of intermodal freight transport, providing transportation equipment, carriage services, and logistical oversight. Both sectors work closely together to ensure the most efficient, cost-effective, and environmentally sound intermodal freight services to support international trade, U.S. industry, and the military supply chain.

Technological advances in intermodal freight transport over the years have made it easier to manage and track the transfer of goods between transportation modes and to coordinate the actions of

the various players involved in moving a shipment through the delivery chain to the end customer. The results have been greater flexibility for shippers and additional opportunities for cost savings.

Innovations in Intermodal Transport

Integrated intermodal transport is critical to the successful execution of national and international supply chains. Most bulk commodities, including food products, natural resources, and large building materials utilize multiple channels of transport to bridge the distance between site of origination and ultimate location of use. Consider grain, for example. In the United States, grain is typically transported from the originating farm via truck before being transferred to containers that travel by rail, water, and/or air before reaching their final destination at home or abroad. Even semibulk or small packages utilize intermodal transport, often moving from truck to rail or air for shipment to ensure the timeliest delivery to final destination in today's increasingly demanding and globalized markets in which sourcing options and trading patterns continue to expand.

In the modern intermodal environment, customers expect highly coordinated and customized delivery of goods via the supply chain. That means that intermodal infrastructure, equipment, technology, and operations must continually innovate to achieve maximum speed, reliability, flexibility, cost-effectiveness, quality, and consistency throughout every stage of the intermodal freight transportation process. Many of the innovations occurring in the intermodal arena have centered on technology.

Technologies such as smart cards, laser scanners, and Global Positioning System (GPS) data inventory tracking have significantly enhanced intermodal freight operations by streamlining processes and increasing visibility along the delivery chain. In the trucking industry, radiolocation technologies have bolstered the logistical management side of intermodal operations by combining automated vehicle location capabilities with voice and data communication channels to facilitate fleet dispatch and timely solutions to unexpected issues along the transport route. Rail transport has been bolstered by real-time grade-crossing, warning system, and interlocking control technologies. Additional innovations in intermodal rail have included the development of an intelligent railroad system with train

control and dispatching functionality to facilitate rail operations and maintenance, a national system to improve tracking and efficiency, and automatic equipment identification tags. Intermodal aviation has been aided by advances in the air traffic control system, including state-of-the-art weather and communication systems, enhanced navigation aids, and direct data links.

Across all modes, further efficiencies are available through application of electronic data interchange technologies that enable easy access to collective information and streamlined controls and processes intended to ensure that transportation efficiencies are maximized.

In addition to transportation system technologies, innovations in the design of intermodal transportation equipment have led to important efficiency improvements. In containerization, for example, design innovations have increased standardization and modularization of freight containers, making it easier, safer, and more economical to move, stack, and ship containers via multiple modes. Special "tanktainers" in which a tank is fitted inside a standard container frame to enable transport of liquids, and lightweight swap-body containers that feature folding legs under the frame to permit easy transfer without a crane are other design advances in containerization that have increased productivity within the intermodal process. The use of advanced materials also has made it possible to increase container capacity and life cycle, reduce overall container weight, and enhance container performance through climate control and other use-related technologies.

In intermodal rail, design enhancements have resulted in flat car improvements such as lightweight articulated rail cars. The modern cars are less costly to purchase, less expensive to maintain, and help protect cargo by eliminating potentially damaging slack action and roll dynamics between railcars. In terms of motor carriers, design advances have provided stronger but lighter trailers that generate fuel efficiency benefits and expand cargo capacities. Design enhancements were also behind the creation of FastShip technology, which couples a patented hull and propulsion system for cargo shipping vessels with dedicated loading systems that enable rapid transit and consistent freight handling almost anywhere around the globe.



A crane lifts a Toll Holdings container off a train in an intermodal container facility in Melbourne, Australia, August 2013. Improvements in freight transport technology have included design enhancements for intermodal railcars such as these. The new cars have lower maintenance costs and are designed to better protect cargo in transit. Other rail transport improvements include the use of the Global Positioning System and automatic equipment identification tags to improve tracking.

Federal Involvement

The Transportation Equity Act for the 21st Century (TEA-21), enacted in 1998 as a successor to the Intermodal Surface Transportation Efficiency Act of 1991, established a strategic planning process to set, monitor, measure, and report on technology research and development priorities related to surface transportation across the United States. In conjunction with TEA-21, the Office of Freight Management and Operations was created in 1999 under the U.S. Department of Transportation's Federal Highway Administration Office of Operations.

The Office of Freight Management and Operations supports the efficient, seamless, and secure flow of freight via the U.S. transportation system and across international borders to help sustain the economy and encourage global connectivity and commerce. Toward that end, the Office of Freight Management and Operations conducts

research, develops analytical tools and data, and assists transportation and planning professionals in obtaining required knowledge and skills to perform their jobs effectively. The organization also reviews state applications for funding, provides funding for significant projects, conducts operational tests of technologies, promotes standards for freight information exchange, certifies state compliance with federal truck size and weight standards, and provides information on state enforcement activities, reporting requirements, and contacts. Taken together, the activities are intended to foster a greater understanding of freight transportation issues and trends, cultivate public/private partnerships, improve operations through advanced technologies, and support the education and training of freight transportation professionals.

The Intermodal Freight Technology Working Group (IFTWG) operates in conjunction with the

Office of Freight Management and Operations. The IFTWG serves as a public–private partnership that pulls from the shared experience and funding of its diverse members to identify, assess, and recommend technology-based solutions to advance safe and efficient intermodal freight movement. The Intermodal Freight Technology program under the Office of Freight Management and Operations is charged with conducting operational tests of recommended intelligent transportation systems (ITS) technologies and developing standards for exchange of electronic freight data.

The ITS is designed to aid cooperation, integration, and technology application for improved productivity among regional transport operations through advanced communication technologies. Intelligent transportation systems range from installed electronics components to wireless technologies that can be integrated into the transportation infrastructure and equipment—including vehicles themselves—to help relieve traffic congestion, enhance transit safety, and optimize the administrative and operational efficiency of commercial and consumer transportation activities. Increased efficiencies consequently reduce operating costs, improve transportation system capacity, and lessen environmental impact.

Benefits

Successful deployment of intelligent technologies in intermodal freight transportation not only provides benefits for the freight network but also delivers significant advantages to both the private and public sectors. In the private sector, the key benefits from intelligent transportation technologies are tied to increased efficiency, enhanced service and reliability, and improved shipment integrity.

In the areas of efficiency and productivity, advances have been driven by better utilization of personnel and equipment. Automated tools that facilitate intelligent freight data have enabled freight operators to reduce administrative burdens, condense processing times, and shorten cycle times. Automated interfaces with regulatory agencies similarly have helped reduce border-crossing delays, nonproductive waiting time, emissions, and wasted fuel due to idling. Improved visibility combined with upgraded control systems have diminished the occurrence of errors overall and increased the speed and ease with which errors are remedied

when they do occur. All these components make it possible to significantly reduce the overall cost of doing business in the intermodal freight arena.

Better visibility and control through the use of intelligent freight technology also has increased operational flexibility and reliability, leading to improved service levels. Intelligent technologies permit operators to maintain schedule adherence by allowing them to identify and address disruptions and delays earlier and avoid shutting down the just-in-time production line. Similarly, carriers have the ability to respond more rapidly to changing priorities tied to in-transit shipments, such as route diversions, and to devise solutions to unexpected problems. The resulting improved reliability and quality of service increase both shipper confidence and overall customer loyalty.

Transportation technology advances have supported improvements in shipment and service integrity as well. Specifically, identification and validation tools such as biometrics and smartcards have increased security by reducing the risks associated with unauthorized pickup and delivery of intermodal freight shipments. Asset tracking technology and onboard sensors also have bolstered shipment security in the post–September 11 environment where the focus of protection has expanded beyond theft and contraband like narcotics to include safeguards against terrorism.

Intelligent freight technologies generate advantages for public enterprises and consumers as well. As in the private sector, public agencies and individuals glean benefits as a result of efficiency, productivity, and service quality improvements deriving from the use of advanced transportation technologies. One of the most significant rewards for the public at large is increased safety as a result of new technology applications. On a national scale, intelligent freight technologies augment security against terrorism and thus contribute to improved overall national safety. On a significant but smaller level, intelligent freight technology deployments can yield important safeguards during the transit process. For example, onboard vehicle sensors may decrease the number of crashes by calling driver attention to faulty equipment such as underinflated tires prior to actual equipment failure. Tools used to monitor driver performance similarly can reduce fleet incidents by identifying potentially unsafe driver behaviors in advance, thereby enabling providers

to educate their personnel on appropriate activity. Motion sensors at weigh-in stations can help improve enforcement and reduce the number of incidents related to overweight conditions of transportation vehicles. The greater visibility provided by intelligent freight technologies makes it possible for public agencies to reward quality shippers and carriers while focusing their enforcement attention on poor performers to yield the greatest benefits.

Superior emergency response is closely tied to safety, and intelligent freight technologies contribute directly to enhancements in that area. Advanced technologies surrounding emergency response warnings have increased the speed of notification regarding hazardous materials incidents, leading to increased effectiveness of incident response and reduced consequences in terms of both environmental mitigation costs and public exposure.

Intelligent freight technologies have led to other environmental and quality-of-life benefits such as reduced traffic congestion and emissions, increased mobility, and improved capacity of the transportation infrastructure. For example, the diminished congestion resulting from easing traffic flows around major transportation hubs like water ports, border crossings, and intermodal terminals means that fewer vehicles are stuck in traffic expending fuel and polluting air quality. Reduced traffic congestion also causes less stress on affected neighborhoods and trims the amount of time wasted sitting in traffic.

Intelligent transportation technologies have improved the quality, efficiency, and economics of intermodal freight networks, enabling better planning, execution, and cost benefits of goods movement via multiple transportation modes globally. The freight network improvements have spurred overall demand and supply for goods and services through the enhanced supply chain, which has stimulated international economic growth and sparked changes in how industry as a whole prices, produces, and delivers its commodities.

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See Also: Air Cargo Carriers; Container Terminals; Containerization/Container Shipping; Emerging Technologies; Federal Transportation Policy; Freight Handling; Freight Terminals; Freight Transport,

Intermodal and Multimodal; Freight Transport, Security Issues; Harbors and Ports, Administration and Operations of; Inland Waterways, Traffic Management and; Intelligent Transportation Systems; Intermodal Surface Transportation Efficiency Act; Railroads, Freight; Transportation Equity Act for the Twenty-First Century.

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Intermodal Surface Transportation Efficiency Act

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA, pronounced ice tea), was the first major federal transportation legislation to shift priority from building interstate highways toward ensuring and maintaining a fully integrated transportation system linking roads, rail, air, and marine transportation to support the nation's increasingly complex needs. This legislation significantly changed the intergovernmental transportation project planning process, restructured the states' reimbursement rates to make nonhighway and maintenance projects more attractive, defined a National Highway System linking major population centers, and strengthened the role of metropolitan planning organizations (MPOs). While the added flexibility for states to divert federal funds to projects such as mass transit did not have as much effect as expected, ISTEA marks a transition away from federal legislation dominated by the highway lobby and opened an opportunity for states to change their patterns of surface transportation spending.

The Legislative and Political Process

By 1991, the interstate highway system was largely complete, but reports showed that many of the nation's roads and bridges needed extensive repairs. With increasing global competition, many cost-conscious U.S. corporations were shifting to just-in-time delivery systems from suppliers and to markets; this added pressure to view a well-functioning multimodal transportation system as a national economic priority. Despite relatively wide consensus on the need for federal action, proposed solutions and ways of paying for them were much more contentious. The final version of ISTEA was the product of significant political compromise, taking elements from Senate and House of Representatives bills that differed both from each other and from the administration's proposed plan.

The Surface Transportation and Uniform Relocation Assistance Act of 1987 (STURAA) was due to expire in February 1991. President George H. W. Bush's proposal to renew it generally maintained the status quo with marginal increases to overall spending, to \$105 billion over five years. His plan proposed designation of a system of highways of national significance and offered lower reimbursement rates to states for projects not considered to have national significance, such as mass transit programs and most noninterstate highways. However, state and local officials would have more power in the project selection process through a highways block grant aimed for those roads not in the primary system.

The Senate bill's primary author was Senator Daniel Patrick Moynihan of New York, chair of the Senate Subcommittee on Water Resources, Transportation, and Infrastructure. Moynihan believed that transportation reform was needed and that continuing to heavily fund new highway construction to deal with congestion was a failing strategy. Moynihan and his allies argued that the funding structures used in prior legislation had encouraged building new highways even when concentrating on maintenance of existing roads or developing other means of transportation would provide more cost-effective or environmentally sound solutions. Whereas the president's proposal offered state and local officials increased project flexibility but provided incentives to direct funding toward a subset of highways, the Senate bill sought to level the playing field among different kinds of transportation projects.

The Senate bill thus reflected the most striking departures from previous policies. In deference to the president, the Senate bill proposed a National Highway System and a Surface Transportation Block Grant. However, the \$123 billion total proposed spending (over five years) was \$18 billion more than the president's plan. It featured a large increase for mass transit funding to \$21 billion (\$5 billion more than requested in the administration plan) and continued operating assistance to existing transit systems. While the Bush plan reimbursed mass transit projects at 50 percent for new starts and 60 percent for capital projects, urban and rural highways at 60 percent, 75 percent for noninterstate National Highway System roads, and 90 percent for interstates, the Senate plan set rates at 80 percent for all types of maintenance projects and 75 percent for new construction. In addition, presumably to combat antiurban bias, Moynihan added more authority for MPOs to be involved in transportation decision making.

Meanwhile, the House Transportation and Infrastructure Committee designed a bill more aligned with the highway lobby's interests. It featured the largest total authorization, \$151 billion (over six years), and kept separate programs and funding levels for urban highways, rural highways, statewide highways, and bridges instead of including the block grant as proposed by the president and Senate. The six-year timeframe was intended to put federal transportation funding on a more predictable long-term basis in line with planning and programming schedules. It also extended half of the five-cent gasoline tax that was set to expire after fiscal year 1995 and introduced measures to ensure states that 90 percent of the federal fuel tax collected in a state would return to that state. The House bill did reflect Senator Moynihan's argument for leveling the playing field by setting reimbursement rates for most programs at 80 percent and at 90 percent to 95 percent for interstate construction and maintenance projects.

The final bill (resulting from Senate and House reconciliation) included the House's six-year scope and \$151 billion price tag but kept many of the innovations proposed by the president and Senate. The final bill's statement of policy declared its mission to "develop a National Intermodal Transportation System that is economically efficient and environmentally sound." While ISTEA's funding

categories matched those of the Senate bill, the funding levels were generally closer to the House's levels. ISTEA also extended the fuel tax and its dedication to the Highway Trust Fund (HTF). ISTEA kept the House's 90 percent Minimum Allocation and Donor State Bonus, intended to address concerns by the states over equity between contributions to and allocations from the HTF. It assured that states would receive at least 90 percent of their respective contributions to the HTF for all highway programs with the exception of special projects. It also ensured that state shares from the HTF would not be reduced from previous years. Funds were also set aside to reimburse states for their costs of constructing highways that were later incorporated into the interstate system.

The creation of a National Highway System and the \$24 billion block grant system were both retained from the Senate bill. Up to half of any state's national highway funds could be shifted to other highway or mass transit projects as long as states could demonstrate upkeep of the designated roads, and those states and metro areas with acute air pollution problems (nonattainment areas) could transfer all funds to mass transit with permission from the U.S. Department of Transportation. Within the \$24 billion Surface Transportation Block Grant, 10 percent of funds were set aside for transportation safety programs and another 10 percent for transportation enhancement activities such as landscaping, converting unused rail corridors to bicycle trails, or removing roadside advertising. States could use remaining funds on a variety of other projects, such as covering planning costs or parking projects. In areas with populations exceeding 200,000, \$9 billion from these funds were required to pass directly to MPOs, allowing them power to make some project selection decisions without state approval for the first time.

ISTEA significantly strengthened the metropolitan planning process and expanded the role of MPOs in this process by requiring their involvement in project selection and transportation decision making. The legislation continued previous planning requirements for MPO involvement in urbanized areas with populations 50,000 and over. Large urbanized areas with populations over 200,000 were designated as transportation management areas (TMAs), and additional planning requirements applied to these TMAs. Each metropolitan area

had to prepare and update a long-range transportation plan and public comment was required before the plan could be approved. ISTEA required MPOs to consider 15 factors in their planning; including, for example, preservation of existing transportation facilities, reviewing and preventing congestion, connectivity of roads within and outside the metropolitan area, efficient movement of freight, and use of life-cycle costing in the design and engineering of bridges, tunnels, and pavement.

Other changes included instituting new planning requirements and management systems for things like traffic congestion and pavement maintenance. ISTEA also added mandatory seat belt and motorcycle helmet safety laws. Failure to adopt these laws by fiscal year 1994 meant automatic allocation of up to 3 percent of a state's highway funds to safety programs. ISTEA also softened the federal stance on tolls, allowing tolls on federal-aid highway facilities to a much greater extent than previous legislation. Initial construction of toll facilities, 4R (restoration, resurfacing, rehabilitation, and reconstruction) work on toll facilities, and conversion of free highways (except interstate highways), bridges, and tunnels to toll facilities became eligible for federal funding.

Implementation and Gradual Change

ISTEA is considered by many to be landmark legislation that has shaped the post-interstate transportation landscape, yet the change it effected was slow to occur. Although ISTEA added considerable amounts of flexibility for states' use of federal funds, most spending patterns did not shift very quickly. With flexibility came a more complex, decentralized planning process, with long-term and short-term statewide transportation plans required for the first time. The U.S. Department of Transportation took nearly two years to issue planning regulations; many states, fearing sanctions, awaited these regulations before implementing major planning process changes. Additionally, most highway and mass transit projects require several years to come through the pipeline from conception to planning and budgeting to construction and use; even if shifting federal funding to other projects had been desirable given the new reimbursement levels and ability to do so, large amounts of funding already were committed to ongoing highway projects. Further complicating matters, most MPOs did not have

staff or procedures needed to assume the full scope of responsibility assigned them via ISTEA.

Another reason for only gradual change under ISTEA was that while the legislation entrusted more power to MPOs, the balance still favored state transportation agencies. Despite mutual veto powers, if the state department of transportation vetoed an MPO's improvement plans, the metropolitan area could lose its ISTEA funds. If the MPO vetoed a department of transportation plan in its jurisdiction, on the other hand, the project might not go through, but the state could apply the funds elsewhere. Hence, even MPOs with the capacity to win consensus on transit projects often hesitated to enter conflicts with the frequently prohighway cultures in the state departments of transportation.

While implementation issues certainly contributed to the slow pace of change, perhaps the largest impediment was the fact that the public simply did not demand change. The great majority of trips in the United States are by automobile. This public preference is also reflected in state laws requiring that state fuel taxes be used for highway construction or maintenance projects. Since most transportation projects are funded by combination of federal and state funds, this creates a further bias toward using federal funds for roads.

ISTEA called for designating a National Highway System so that states would focus federal funds on infrastructure critical to maintaining a nationwide transportation network, but the law did not specify which roads would supplement the Interstate Highway System to form it. State, local, federal, and Department of Defense officials had two years to identify a system of high-priority routes considered essential for interstate and international commerce, defense, and access to intermodal transfer points, which was subsequently authorized through the National Highway System Designation Act of 1995. The resulting 160,000-mile system was only 4 percent of the nation's public roads, but it carried more than 40 percent of its highway traffic, 75 percent of freight traffic, and 90 percent of tourist traffic.

ISTEA required states to develop and implement management systems for pavement, bridges, safety, congestion, public transportation, and intermodal systems. These systems were meant to encourage efficient and effective maintenance decisions. For each system, states were to identify performance measures, collect data, and determine appropriate

strategies to address any problems. Interim rules issued in December 1993 set a timeline for full systems compliance by October 1996—just before ISTEA was set to expire.

Legacy

ISTEA's legacy is a mixed one. On one hand, ISTEA marked a sharp departure from a U.S. consensus that building highways was the sole priority of federal transportation legislation. Those hailing it as revolutionary have a legitimate basis for doing so; it rewrote the planning process and changed state-local relationships within it, leveled funding so that pursuing projects other than highways became more attractive, and established an intermodal, systemic paradigm for prioritizing spending. As a direct consequence of the more distributed planning process, planning and administrative costs more than tripled in the next 10 years, from \$267 million to \$893 million, and subsequent transportation bills struggled to find a balance between streamlining the process for practicality and adding even more required considerations and stakeholder participation.

On the other hand, substantive changes based on this broader focus were slow to develop. While the amounts of money flexed toward nonhighway projects increased every year under ISTEA, by the end of 1996, states transferred only 4 percent of the funds that they could, and almost all of that occurred in just three states. The extended difficulties passing TEA-21 and SAFETEA-LU, the next two reauthorizations for overall federal transportation funding, confirmed transportation policy's move toward conflict politics, but these bills also continued ISTEA's direction toward incorporating intermodal and environmental concerns.

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See Also: Federal Aid Highway Program; Federal Transportation Policy; Just-In-Time Systems; Metropolitan Planning Organizations; Moving Ahead for Progress in the 21st Century Act; National Highway System Designation Act of 1995; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Transportation Equity Act for the Twenty-First Century.

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International Air Passenger Transport

Air transport is a major driver of social and economic change. Despite recent economic shocks and a general downturn, air transport remains resilient, with the major aircraft manufacturers—Boeing and Airbus—forecasting that world passenger traffic will continue to grow 5 percent annually over the next 20 years. International air transport is increasingly important for a number of economic reasons. For example, it enables the movement of perishable and high-value goods over long distances efficiently and facilitates face-to-face business interaction. The following, however, focuses on the passenger side of the international air transport industry. It will look at the social and individual effects and attributes of this mode and examine the ways in which air travel benefits people worldwide.

Air travel demand has grown by around 5 percent annually for the past 20 years according to the International Air Transport Association (IATA). Even in 2012, when economic activity and prospects globally had not been particularly optimistic, there was a 5.3 percent increase in passenger demand. Now, over 51 percent of international tourists travel by air, according to the Air Transport Action Group (ATAG). Recent forecasts by the U.S. Federal Aviation Administration (FAA) suggest that airline passenger travel will almost double in the next 20 years. In 2011, over 2.8 billion people were carried by airlines around the world. In addition, ATAG reports that, worldwide, more than 56 million people work in aviation and related tourism jobs. This shows that international passenger air transport continues to be central to an ever more connected world.

Traditionally, air passenger transport has been seen as a major driver of tourism, with the establishment of routes between source locations and tourist destinations seen as key to encouraging inward investment in the local industry and allied tourism infrastructure. Thus, international air passenger transport was an important development tool in areas such as the Caribbean and the southern European destinations of Spain and Portugal.

In less developed countries, air transport provides a vital component of the tourism package and is seen as a main device to drive economic growth and consequent poverty reduction. The United Kingdom think tank, the Overseas Development Institute, suggests that three-quarters of tourist journeys start in a high- or upper-middle-income country and 40 percent of these end in a developing country. This highlights the importance of international tourism, and thus air passenger transport, to the transfer of financial resources to countries where they can help alleviate economic challenges.

In terms of governance, the International Civil Aviation Organization (ICAO) is a specialized United Nations agency that works toward the safe and orderly functioning of worldwide civil aviation. To this end, under the framework of the 1944 Chicago Convention on International Air Transportation, it provides the standards and sets out the regulations for aviation safety, security, efficiency, and regularity, as well as environmental protection with respect to aviation.

The ICAO was also responsible for developing the system of air traffic rights, known as freedoms of the air. While national governments are responsible for their own aviation policies, they work with other countries to negotiate bilateral agreements to allow international air transport between the two nations. This can result in a complex web of more than 10,000 bilateral air services agreements (ASAs) between each pair of countries. In air services negotiations between countries, the freedoms of the air provide the framework of rights around which agreements are made. ICAO's *Manual on the Regulation of International Air Transport* sets out these freedoms as follows:

First Freedom of the Air. The right or privilege, in respect of scheduled international air services, granted by one State to another State or States to fly

across its territory without landing (also known as a First Freedom Right).

Second Freedom of the Air. The right or privilege, in respect of scheduled international air services, granted by one State to another State or States to land in its territory for nontraffic purposes (also known as a Second Freedom Right).

Third Freedom of the Air. The right or privilege, in respect of scheduled international air services, granted by one State to another State to put down, in the territory of the first State, traffic coming from the home State of the carrier (also known as a Third Freedom Right).

Fourth Freedom of the Air. The right or privilege, in respect of scheduled international air services, granted by one State to another State to take on, in the territory of the first State, traffic destined for the home State of the carrier (also known as a Fourth Freedom Right).

Fifth Freedom of the Air. The right or privilege, in respect of scheduled international air services, granted by one State to another State to put down and to take on, in the territory of the first State, traffic coming from or destined to a third State (also known as a Fifth Freedom Right). ICAO characterizes all “freedoms” beyond the Fifth as “so-called” because only the first five “freedoms” have been officially recognized as such by international treaty.

Sixth Freedom of the Air. The right or privilege, in respect of scheduled international air services, of transporting, via the home State of the carrier, traffic moving between two other States (also known as a Sixth Freedom Right). The so-called Sixth Freedom of the Air, unlike the first five freedoms, is not incorporated as such into any widely recognized air service agreements such as the “Five Freedoms Agreement”.

Seventh Freedom of the Air. The right or privilege, in respect of scheduled international air services, granted by one State to another State, of transporting traffic between the territory of the granting State and any third State with no requirement to include on such operation any point in the territory of the

recipient State, i.e the service need not connect to or be an extension of any service to/from the home State of the carrier.

Eighth Freedom of the Air. The right or privilege, in respect of scheduled international air services, of transporting cabotage traffic between two points in the territory of the granting State on a service which originates or terminates in the home country of the foreign carrier or (in connection with the so-called Seventh Freedom of the Air) outside the territory of the granting State (also known as a Eighth Freedom Right or “consecutive cabotage”).

Ninth Freedom of the Air. The right or privilege of transporting cabotage traffic of the granting State on a service performed entirely within the territory of the granting State (also known as a Ninth Freedom Right or “stand alone” cabotage).

The term *cabotage* is defined in more detail under the 1944 Chicago Convention as the following:

Each contracting State shall have the right to refuse permission to the aircraft of other contracting States to take on in its territory passengers, mail and cargo carried for remuneration or hire and destined for another point within its territory. Each contracting State undertakes not to enter into any arrangements which specifically grant any such privilege on an exclusive basis to any other State or an airline of any other State, and not to obtain any such exclusive privilege from any other State.

This background of complex intercountry negotiation over air links highlights the dominance of this mode as a facilitator of travel across national boundaries. Air transport enables larger distances to be traveled with greater speed than any other mode, and for business travel, it provides connections across a global marketplace. For leisure travelers, air transport facilitates trip-making that satisfies a number of needs. It can form an important part of a wider tourism package, enabling visits to recreational destinations such as the cities of Europe (the region with the highest inbound international traffic flows). It can also be an enabler of travel that strengthens and binds people’s social links, as it allows those who are located in home countries to



A moving walkway at Chicago's O'Hare International Airport. O'Hare is among the busiest airports in the world, consistently ranking among the top 10 in the world in terms of number of passengers. The airport served nearly 66.8 million passengers out of the total 2.8 billion people carried by airlines worldwide in 2011. Over 51 percent of international tourists travel by air, and airline passenger travel around the world is expected to almost double in the next two decades.

visit those who now live overseas and vice versa. The importance of such travel can be seen on a daily basis at airports such as Miami International, where passenger flows between Latin America and the Caribbean and South Florida form a key component of traffic volumes.

Turning now to some of the important themes in passenger air transport, the most dominant change in the industry over the past 15 years has been the rise of the low-cost carrier. It began with Southwest Airlines in the 1970s, and by the 2000s several airlines with a similar model of service were in operation. Their success is based on high aircraft and seat utilization rates, low fares, no-frills, point-to-point service (often into secondary airports where charges may be lower), and quick aircraft turn-arounds. These airlines tend to operate on shorter haul routes, facilitating travel in dense markets such as Asia and Europe. Along with Southwest, Ryanair

and AirAsia are some of the other dominant carriers in this industry sector. In terms of the direct social impact of such operators, they have been seen to offer more people the opportunity to fly and others the opportunity to fly more often and this, in turn, has resulted in a normalization of travel by air. The carriers serve both the business and leisure markets with an estimated split of 30 percent to 70 percent between these two sectors. With respect to leisure, these operators serve a number of areas of demand, in Europe, for example, enabling travel such as visiting friends and relatives (VFR), people going abroad for winter sun, those with second homes, and those traveling to celebrate bachelor or bachelorette parties.

The apparent rising propensity to travel raises the issue of harmful carbon emissions related to such passenger movement. In response, carbon offsetting has been seen as a way of assuaging some of

such concerns. IATA describes this approach as a way for airline passengers and corporate customers to “neutralize” their proportion of an aircraft’s carbon emissions on a particular journey by investing in carbon reduction projects. It sees carbon offsetting as an immediate, direct, and pragmatic means to encourage action to limit climate change impacts, at least in the short term.

Another area of concern that has arisen concomitantly with increased air traffic volumes is the greater possibility of air rage incidences. In 2000, such an incident aboard a Southwest Airlines flight resulted in the death by suffocation of a disruptive 19-year-old passenger. It has been reported that since September 11, 2001, there have been a greater number of air rage incidents, resulting in headlines such as “Drunken Air Rage Granny Punched Passenger in Face After He Asked Her to Be Quiet” and “Air Rage Briton Pictured With Black Eye After Offering to Fight Everyone on Board Holiday Jet.”

As demand for air travel continues to grow, capacity constraints at airports will become increasingly important. One geographic area that is already severely constrained is London. The two main airports, Heathrow and Gatwick, are highly constrained, and there is a need for expansion of available capacity if further traffic growth to meet demand is to be facilitated. Yet, locating new infrastructure such as runways in the southeast of England is highly contentious due to public concerns about noise, pollution, and associated road infrastructure development. As people continue to want to fly, similar debates will become more prevalent worldwide, particularly in largely urbanized destinations with physical limitations on potential for capacity expansion.

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See Also: Air Passenger Carriers; Air Travel; Airline Industry; Airline Passengers; Aviation, Commercial/Business; International Travel; Recreational Travel.

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International Customs and Duties

In 136 C.E., Palmyra, an ancient oasis city in the central Syrian Desert, levied one of the first customs tariffs on record, outlining tax rates for commodities being imported through Palmyra for the Roman Empire. Emperor Hadrianus assigned Palmyra the role of collecting municipal customs duties, and the tariff documentation was engraved on a stone pillar in Greek and Aramaic. Salted goods carried by donkey were assessed “three denarii per load at importation and exportation.”

Throughout centuries of human history, nations have initiated and attempted to control trade because of its economic importance. Unlike many taxes, customs duties on imports and exports were easy to collect, and they became one of the most reliable sources of public revenue. In the modern-day era of globalization, nations have banded together and created international and national customs and trade associations to classify imported and exported goods and manage and regulate customs duties. Besides customs agreements with other countries, individual nations operate their own customs agencies to establish and enforce customs laws. Travelers entering and leaving a country with merchandise must negotiate a patchwork of customs regulations, but the trend seems to be moving in the direction of customs and duty globalization to match trade globalization.

World Customs Organization

Headquartered in Brussels, Belgium, the World Customs Organization (WCO) has gained worldwide recognition for its development, promotion, and implementation of modern customs and procedures. The WCO maintains the international Harmonized System (HS) of goods classification and administers the technical aspects of the World Trade Organization (WTO), Agreements on

Customs Valuation, and Rules of Origin. In the 21st century, WCO members are responsible for customs controls on more than 98 percent of all international trade.

The WCO has created a number of customs systems to achieve its objectives. In 1988, the International Convention on the Harmonized Commodity Description and Coding System (HS Convention) was adopted as a system of naming and compiling international trade statistics. It has a database of about 5,000 commodity groups arranged in a legal and logical structure with rules to achieve uniform classification. The HS Convention is also used for other customs purposes, including monitoring controlled goods, internal taxes, freight tariffs, and economic research and analysis.

Implemented in 2006, the International Convention on the Simplification and Harmonization of Customs procedures, the revised Kyoto Convention (or RKC)—not to be confused with the United Nations Kyoto Protocol on Climate Change—is composed of several key governing customs principles. Some of the principles include transparency and predictability of customs controls, standardization and simplification of the goods declaration and supporting documents, maximum use of information technology, and minimum necessary customs control to ensure compliance with regulations.

Both the ATA Convention (the term *ATA* is a combination of the initial letters of the French words *admission temporaire*) and the Istanbul Convention are arms of the WCO governing temporary admission of goods. The ATA system, integral to both conventions, allows goods to freely move across frontiers and temporarily admits them into a customs territory with duties and tax relief. A single document called the ATA Carnet secured by an international guarantee system covers the goods.

The Arusha Declaration on Customs Integrity is a nonbinding document that elucidates basic principles to promote integrity and fight corruption within customs administrations.

Adopted in 2005, the SAFE Framework of Standards to Secure and Facilitate Global Trade is a nonbinding agreement setting supply chain security and facilitation standards for goods being traded internationally and champions the seamless movement of goods through secure international trade supply chains.

Federation of International Trade Associations

Founded in 1984, the Federation of International Trade Associations (FITA) encourages international trade by strengthening the role of local, regional, and national associations with an international mission throughout the United States, Mexico, and Canada. The FITA's 450 members and 450,000 linked company members are dedicated to promoting international trade, import-export, and international finance. Members include freight forwarders, airlines, shipping companies, port authorities, trading companies, and telecommunications companies.

The Tariffs and Customs section of the FITA Web site features tariff rates for the 21 members of the Asia Pacific Economic Cooperation Tariff Database and AsiaCalculator, a search engine that figures the applicable customs duty for imports from Asia. It lists China Import Tariffs, customs information for over 100 countries, global tariffs for the United States, Canada, Mexico, and European Union (EU) tariff schedules, customs information about Russia, and information about Swiss customs.

European Customs Union

Countries have banded together to facilitate trade and navigation customs on the national level as well. In July 1968, Belgium, France, Germany, Italy, Luxembourg, and the Netherlands solidified the founding of a customs union planned under the 1957 Treaty of Rome. Though the European Customs Union and the European Union rules include caveats that there be no customs duties at borders among EU member states, there are common customs duties on imports from outside the EU and common rules of origin for products from outside the EU apply. There is a common definition of customs value.

All member states of the European Union form a customs territory, the European Customs Union, where unified customs arrangements apply. When goods are imported into the EU countries, they are covered by EU-wide customs, tariffs, and customs procedures, but once goods have been imported and duties paid, no more duties may be charged even if the goods cross the borders of member states.

Eurasian Economic Union

The heads of Russia, Belarus, and Kazakhstan laid the foundation for a Eurasian Economic Union in

spring 2013, using the European Union as a model. They said that the agreement on the Eurasian Economic Union would be based on a code of laws, more than 70 agreements. Combining all of the laws would be the basis of an economic union. The three countries also discussed rules for allowing other formerly Soviet countries to join the existing customs union between Kazakhstan, Russia, and Belarus.

Southern African Customs Union

An alliance between South Africa, Botswana, Lesotho, Namibia, and Swaziland, the Southern African Customs Union (SACU) is one of the oldest customs unions in the world, established in 1910 as a Customs Union Agreement between what was then the Union of South Africa and the High Commission Territories of Bechuanaland, Basutoland, and Swaziland. The union went through some evolutions and country renaming to reach its present configuration.

The five member countries of SACU apply the same rates of duties on imported and locally manufactured goods, and all customs and excise taxes are paid into South Africa's national Revenue Fund to be shared among members according to a revenue-sharing formula. South Africa also has customs agreements with other countries including France, the Netherlands, the United Kingdom, and the United States.

Mercosur

Argentina, Brazil, Paraguay, and Uruguay are members of Mercosur, the Common Market of the South. Argentina, Brazil, Uruguay, and Paraguay founded the Mercosur customs union in 1991, with Bolivia, Chile, Colombia, Peru, and Ecuador participating as associate members. The goal of Mercosur is to streamline import and export duties as much as possible while allowing members to keep their autonomy.

Being part of Mercosur is both a positive and a negative experience for countries belonging to the customs union. For example, Mercosur states charge 20 percent duty on any automobile imports and 11 percent on raw material imports. Argentinian import duties begin with Mercosur rates. In addition to Mercosur tariffs, Argentina imposes value added taxes (VATs) to imports that are divided into two types: simple imports and goods imported specifically for resale. Argentina taxes simple imports at 21 percent, or 10.5 percent for specific industries

like steel or petrochemicals. Goods imported for resale are taxed at 10.5 percent and 5.5 percent to stimulate economic growth.

Protectionist rules within Mercosur frequently cause disagreements. In early 2013, Argentina and Brazil levied nonautomatic import licenses on a variety of goods that they trade back and forth, angering industrialists on both sides of their common border. Business leaders from Uruguay complained for months that Argentina blocks imports from their country.

North American Free Trade Agreement

Because of their common borders, the United States and Canada and the United States and Mexico have historically negotiated trade agreements, but the North American Free Trade Agreement (NAFTA) superseded them all. On January 1, 1994, Mexico, the United States, and Canada, entered into the NAFTA customs agreement, which removed barriers to trade and investment between the United States, Canada, and Mexico. NAFTA created one of the world's largest free trade zones and built the foundations for strong economic growth and rising prosperity for Canada, the United States, and Mexico.

NAFTA eliminated all nontariff barriers to agricultural trade between the United States and Mexico; many tariffs were eliminated immediately while others were phased out over periods of five to 15 years. Mexico and Canada reached a separate bilateral NAFTA agreement about market access for agricultural products, eliminating most tariffs either immediately or over five, 10, or 15 years. The two countries maintained tariffs affecting trade in dairy, poultry, eggs, and sugar.

In 2012, NAFTA had a combined output of \$17 trillion across North America, with the most popular exports from Canada to the United States including mineral oil, fuel, motor vehicles, machinery, wood, and electrical machinery. NAFTA helped provide Canadian businesses with better access to materials, technologies, investment capital, and talent across the rest of North America, giving Canadian businesses a competitive advantage compared to suppliers who did not belong to NAFTA.

As part of the free trade agreement, Canada, the United States, and Mexico enjoy favorable if not duty-free terms of trade, but customs agencies require a certificate of origin to confirm that a product was made in a NAFTA country before it can be

classified as duty free. This enables customs officials to quickly decide which goods qualify for preferential tariffs and which require only minimum processing. Another requirement is to clearly outline the origin of the raw materials in a product. Failure to do this puts businesses at risk of being charged a penalty and of the goods being charged duty at a later time, duty that could be up to 20 percent of the value of the goods.

Trade between the United States and its NAFTA partners has soared since the agreement took effect. The United States had \$918 billion in total (two-way) goods trade with Canada and Mexico during 2010. Goods exports totaled \$412 billion and goods imports totaled \$506 billion.

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See Also: Freight Rates/Tariffs; Global Economic Centers; Globalization; Transportation, Economics of.

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International Rail Transit

Over the next four decades, global passenger and freight travel is expected to reach double the 2010 levels. Depending on the scenario used to evaluate present data, the transport sector's energy consumption and emissions are projected to increase from 40 to 80 percent by 2050. Growth in global transportation will have consequences far beyond energy and emissions through the course of this expansion.

Infrastructure for the surface transport sector must increase significantly to 2050, as global mobility surges. Various analyses show that it is expected that the world will need to add nearly 208,000 miles (335,000 kilometers) of rail track and 15.5 million miles (25 million kilometers) of paved roadway, a 60 percent increase over 2010 combined rail and road network length by 2050.

Regional Impacts

Nonmembers of the Organisation for Economic Co-operation and Development (OECD) regions will account for nearly 90 percent of global travel increases. The largest expected infrastructural additions will be in rapidly emerging economies, such as China and India. Southeast Asian nations, Latin America, and the Middle East are also expected to contribute considerable land transport infrastructure between now and 2050. By 2050, non-OECD transport infrastructure investment and maintenance spending levels are anticipated to be nearly 20 percent higher than in OECD countries.

Although many parts of the world experienced a recession over the past decade, global average per capita gross domestic product (GDP) increased (in real U.S. dollars), with average per capita GDP in regions such as China, India, southeast Asia and eastern Europe more than doubling. This growth in wealth has contributed to a demand for mobility, both in terms of passenger travel and in movement of freight. Surface travel increased by 40 percent in one decade, and Asia and the Pacific, in particular, accounted for more than half of that growth.

Many countries in Europe and Asia have embraced effective policies and invested significant funds in their rail and transit sectors, especially for intercity passenger rail. (The United States currently lags far behind global competitors in terms of expenditure relative to population.) Some of the nations that have invested

the most in rail infrastructure are (in descending order from \$12.50 to \$0.20 per \$1,000 GDP, 2008): China, Switzerland, Austria, India, United Kingdom, Spain, Netherlands, Sweden, Russia, France, Italy, Germany, United States, and Turkey. It was expected that the stimulus funds under the American Recovery and Reinvestment Act of 2009 (ARRA) would substantially increase the U.S. amounts invested in rail transit.

Car Comparison

Transit patronage in the United States is now 23 percent higher than in 1993 and growing faster than car usage. The growth has been particularly strong since about 2003 and has continued since 2008. There seems to be a resurgence in the United States in the popularity of utilizing mass transportation modes. All of the growth in ridership since 1993 has been on rail-based modes.

Rail modes have increased their shares of total patronage, particularly heavy rail, from about 25 percent to 35 percent of the total. (Bus share has significantly declined from 65 percent to 50 percent.) The patronage on light rail has increase rapidly from a relatively small base of 168 million users to 481 million users over the same period.

The century-old growth of automobile use in metropolitan areas appears to have plateaued and even declined across the world's developed cities. European cities historically have built more infrastructure to accommodate more cycles and transit systems and are less dependent on the automobile. Compared with the United States, European governments have made a serious commitment to rail and transit investments. This is reflected in the region's more extensive and denser networks, as well as its more balanced modal split. (About 16 percent of all European passenger travel is undertaken by bus and rail, compared with a mere 4 percent in the United States.)

The cities in Asia and the Middle East have also invested large amounts of capital in mass transportation infrastructure. In the face of challenges such as high gasoline prices, traffic congestion, and carbon emissions, public transportation offers a range of benefits over private automobile travel.

Rail ridership is on the rise in many countries. With many new systems under construction or in the planning stages, orders for rail vehicles are expected to show strong growth in the coming

years—and these orders will translate into employment growth.

Much of the current ambition is directed toward the expansion of intercity high-speed rail (HSR) lines. In 2009, HSR lines totaling some 6,650 miles (10,700 kilometers) worldwide were operational. In 2008, the world's HSR fleet consisted of some 2,200 trains. The vast majority of these were in western Europe, followed by Asia, with most of them in Japan. Listed in order of their national track-building projections between now and 2025, the front runners include China, Spain, France, Japan, Turkey, Germany, Italy, Poland, Portugal, the United States, Sweden, Morocco, Russia, Saudi Arabia, Brazil, India, Iran, South Korea, Argentina, Belgium, the Netherlands, the United Kingdom, and Switzerland.

Major Markets

Currently, the leading global rail manufacturers are Bombardier of Canada, Alstom of France, and Siemens of Germany, but they are increasingly challenged by China's China South Locomotive and Rolling Stock (CSR) and China Northern Locomotive and Rolling Stock (CNR). Smaller but significant manufacturers include Ansaldo-Breda of Italy, CAF (Construcciones y Auxiliar de Ferrocarriles) and Talgo of Spain, Stadler of Switzerland, and Hyundai Rotem of South Korea. (Japanese competitors are part of large industrial conglomerates.) Four nations that have retained significant manufacturing employment in the rail and transit industries, and are also global leaders in rail transit growth, are Germany, Spain, Japan, and China.

Germany is one of the largest rail and transit markets in the world. Its rail manufacturing industry is a global technology leader; it has strong internal demand and even larger export sales. Germany's per capita investments in rail and transit are double those of the United States. However, rail advocacy groups argue that the German government is not investing enough in rail infrastructure. A comprehensive joint assessment by rail operators and rail manufacturers likewise concluded that intercity and urban rail investments of about \$9.3 billion per year are needed from 2008 through 2015 to keep pace with ridership.

Spain maintains the largest high-speed rail construction program in Europe. Its rail travel increased 55 percent between 1990 and 2008, far

outstripping its population growth. The government's 2004 Strategic Plan for Infrastructures and Transport (PEIT) still serves as a powerful planning tool, and the two-year Extraordinary Infrastructure Plan of April 2010 allocates 70 percent of the country's \$24 billion in transportation funds to rail. The HSR network of Spain has surpassed Germany's in length and in 2009 was second only to France's in all of Europe.

Japan was the first nation to implement high-speed rail development (in 1964) and continues to be a global leader. Japan has developed a strong capacity for the operation of high-quality rail service. Though the country's population rate is declining, rail ridership remains relatively high. Japanese train manufacturers are looking increasingly to the global market; their exports accounted for more than one-third of their revenues over the past decade.

China's leadership has embraced a highly ambitious plan to expand the country's intercity rail network, possibly reaching 93,000 miles (150,000 kilometers) by 2020, including 16,000 miles (26,000 kilometers) of high-speed lines. China is expected to account for more than half of global rail equipment expenditures in coming years. The country's two dominant rail manufacturing companies, CSR and CNR, together employ more than 200,000 people directly.

When it comes to rail and transit, the United States has not had a coordinated infrastructure investment and industry development policy for several decades. Meanwhile, China's focus on appropriating and absorbing foreign technology has been spectacularly successful to date. The country's decision makers have been aggressive about using their huge market as a lure for foreign companies. The United States offers a potentially huge market—assuming that, like China, it is willing to prioritize rail and transit investments.

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See Also: High Speed Rail, Design and Technology of; International Travel; Rail Transit Planning, Worldwide; Surface Transportation Program; Transit Industry, Economics of; Transit Lines/Networks; Transitways; Transportation, Economics of; Transportation Planning.

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International Travel

The United Nations World Tourism Organization (UNWTO) reports that in 2012, for the first time, 1 billion people traveled across their national borders—a comprehensive demonstration that there is an ever-increasing desire and propensity to travel farther from home and between different countries. The UNWTO states that globally, as an export category, tourism ranks fourth after fuels, chemicals, and automotive products. Lifestyle changes, increased personal affluence, and migration are some of the key factors that have resulted in this upward movement in demand for international travel. This greater individual mobility has also been matched by increases in accessibility of modes such as air for more people, largely associated with the rise in low-cost carriers, their affordability, and the greater connectivity they provide to a variety of destinations.

UNWTO figures also suggest that just over half of all tourists in 2012 were from Europe, while one-fifth came from Asia/Pacific and another fifth from the Americas. In addition, these statistics show that people tend to choose these three regions as their destinations and that half travel for leisure, a quarter for visiting friends and relatives (VFR), and 15 percent for business purposes. In order to demonstrate the economic dimensions of such travel, the U.S. Travel Association reports that \$244.16 billion is spent each year for business travel, an amount that represents one-third of total U.S. travel spending.

While air may be the leading mode for international travel, such movement is also undertaken using a number of other modes: coach, rail, maritime, and even foot (for some of those who venture to cross borders between states, either as a leisure activity or to try to access better life opportunities in another country). However, most of the international travel that takes place tends to be dominated by air transport, a mode that enables greater distances to be traversed more quickly than other options. Business travelers rely heavily upon the mode to enable economic connectivity across a networked, global marketplace.

Taking another viewpoint, air travel is important to the maintenance of social and cultural links between people at home and those located overseas in the diaspora (people who are living away from their homelands). For these people, air transport links provide a bond that facilitates the construction of transnational identity and citizenship and can serve to maintain social networks and intensify personal association with “home,” however distant it may be temporally or geographically. In addition, air transport plays an important role in another sector: it is equally valuable to people who wish to visit other countries during their leisure time.

Travel motivation appears to be fundamentally focused on a desire to maximize one’s own well-being or satisfaction. Concentrating on international leisure travel and briefly considering the variety of people’s motivations to visit particular destinations reveals the true scope of desire for international travel. This list indicates some of the diversity of activities in which people may wish to participate, which would, in turn, determine their chosen destination:

- Specific religious, pilgrimage, and other holy activities such as visits to the Vatican and attending the Haaj
- Extreme sports and other risky activities such as bungee jumping and paragliding in New Zealand, scuba diving in Greece, or skiing and snowboarding in Switzerland or the United States
- Sun seeking (sometimes described as sun, sea, sex, and sand travel) in destinations such as the Caribbean and southern countries of Europe
- Visiting historic sites such as Machu Picchu in Peru or the Taj Mahal in India
- Scientific travel to places such as Antarctica
- Cultural travel and making connections between migrant families
- Medical tourism, wherein people travel to access medical care unavailable at home
- Young adult travel such as gap year, backpacking, spring break

At the same time, the rising economic prosperity of countries such as Brazil, Russia, India, and China (the BRIC countries) and a concomitant emerging middle class has resulted in a related increase in international travel from these origins. Projections suggest that these and other similar countries will continue to be important drivers of travel abroad. International travel patterns change with time: for example, where once travelers may have been mainly attracted to historical and cultural sites, there are now also concurrent movements of people seeking to purchase key brands in chosen cities, that is, the expansion of shopping travel and pursuit of brands in destinations such as Paris, London, and New York by visitors from origins such as China, Russia, and South Africa. Similarly, Indian travelers may also visit souks, bazaars, and shops in the Middle East for gold.

International air travel operates within an international and national framework made up of policies, procedures, and processes working together to maintain a smooth and safe operation of the industry. Such structures are formulated with social, economic, and environmental objectives at their fore, as well as taking account of regulatory/deregulatory and legal constructions that provide parameters for the operation of the transport mode at national and international levels. Other modes also operate within defined structural frameworks, although these are less complex and restrictive than those for aviation. Within a primary focus upon social issues around international travel in this article, greater exploration of these organizational models is less important here than simply allowing that they exist as a background and facilitator of all the activity described herein.

Nevertheless, while all social and economic indicators suggest that demand for international travel appears likely to continue, there are concerns about

the capacity for infrastructure, such as runways and terminals, to meet such requirements. Looking specifically at aviation, there is increasing awareness of the impacts of airports on surrounding communities and environmental and other land-related limitations on further airport expansion to supply the projected demand. This raises the issue of sustainability of international travel, with ideas around this theme being regularly discussed in contemporary air transport and tourism discourse. Nevertheless, in terms of local communities, there can be large-scale benefits of international travel. The World Bank indicates that tourism entails investments in public works: roads, water and sewage systems, hospitals, communications, and transport systems that will not only attract hotel and tour operators but can also provide people living in the area with improved resources and services.

However, there is little doubt that air travel impacts on the environment. It enables people to travel much greater distances and, thus, means that their travel is associated with a greater contribution to greenhouse gas production than local travel would have been. The aircraft themselves are also larger scale producers of emissions than those related to other modes and this, in turn, contributes to increased carbon monoxide in the atmosphere, leading to potential climate change effects. There are also important noise considerations in proximity to airports, resulting in curfews and flight path restrictions implemented to assuage effects on local communities.

High Speed Rail

A potential solution to these sustainability concerns may be found in high speed rail (HSR). For example, in Europe, as concerns rise about environmental effects of air transport, there have been political and practitioner suggestions that high speed train (HST) services could result in modal shift (movement of passengers from the use of aviation to rail). However, the extent to which rail can yet compete with air is less clear. While it has been reported that, on routes between city pairs such as Paris and Brussels, improvements in rail journey times have resulted in a decrease in demand for air services on the route, it seems that low-cost carriers continue to dominate the European market in general. Travel time is an important factor in passenger choice of mode, and this is likely to be one of the main areas in which air travel continues to have the advantage

in Europe. In addition, Boeing reports that in 2010, worldwide railways carried 45 percent less passenger traffic than commercial aviation and that the total distance covered by railway networks was 2.5 percent that of the aviation network. The aircraft manufacturer goes on to state that data analysis suggests that rail is suited for carrying passengers over relatively short distances.

Notwithstanding these findings, there are some international rail journeys that have existed for many years and, in contrast to many other aspects of passenger transport use, demand for these trips appears to be for the actual travel experience rather than the more traditional perception that travel is a derived demand, that is, it is something that is undertaken as part of a desire to satisfy another need (that of arriving at the chosen destination). Examples of such services are the Trans-Siberian Express, Rovos Rail Pride of Africa, and the Venice Simplon–Orient Express, where transport itself forms a main part of the focus of the journey.

Ocean Cruising

Cruising is another example. It is one of the fastest growing sectors of the international travel market. For example, the United Kingdom–based Passenger Shipping Association reports that UK ports are projected to handle 1 million cruise passenger embarkations in 2013 and that more passengers than ever embarked and called at British ports in 2012, with cruising accounting for one in every eight of all package holidays taken. In addition, there has been an accompanying expansion in the available passenger capacity worldwide (with 13 ships with 14,886 new beds launched in 2011). The entire experience onboard, as well as the idea of visiting other countries, appears to attract people to take this type of vacation. Importantly, lowering of fares has led to a larger pool of people being able to afford to go on a cruise. Traditionally, this type of travel was seen as safe and leisurely. Nevertheless, the social impacts of this industry are also relevant to the discussion of international travel here. Labor exploitation of those who work onboard, commercialization and congestion of ports, and environmental impacts on destinations are some of the issues that are of concern. In addition, there have been recent headlines about cruise ship safety issues, such as breakdowns and fires, that have brought the models of operation of the industry into focus.

Looking briefly at some of the ethical issues around cruise ship operation illustrates further the multifaceted nature of international travel. Cruise ships are staffed by people from a diversity of ethnicities and cultures who live in close proximity on lower decks of the vessels and work long hours to ensure the successful operation of all the upper-deck activities. The economic disparity between the crew and the passengers is just one feature of the close interaction between staff and customers and the moral discomfort it can potentially engender.

Expanding on the topic of ethical concerns around travel in general leads to consideration of issues related to the impact of tourists on traditional cultures, practices, and lifestyles. International travel has enabled access to a number of destinations whose popularity means they can be overrun by tourists at certain times of the year. Thinking first of impact on social activity in an urban space and considering a destination such as Edinburgh in the UK in the summer when the castle, festival, and general tourist attractiveness can mean the place is so busy with visitors that local people can find it hard to go about their own business easily in the city. At the other end of the development spectrum, a small island such as St. Vincent in the Grenadines may be highly dependent upon tourism economically, but it may also experience being overwhelmed by tourist flows, with net effects upon the ways in which people adapt their lifestyles and practices to satisfy the needs of the visitor. For example, sex tourism and all its attendant accoutrements have been features of Caribbean tourism as the region's dependency upon the industry has developed. This raises ethical and moral considerations for local people and cultures. Thus, while economic benefits are undoubtedly being funneled into the local business environment, the social impacts may not all be as beneficial as may be thought initially.

Information Availability

One of the most important attributes of contemporary international travel is the wide range of resources that are available for considering options for travel and then booking that travel. The information and communications technology (ICT) revolution continues to fuel the availability of media for purchasing travel, and this disintermediation (essentially, the removal of the middleman—travel agents, in this case) has meant that people have had greater access

to international transport information and, thereby, been able to make bookings more easily and, with increasingly portable devices, on the go.

Virtual Mobility

Despite the rise in tools that facilitate communication across spatial distance such as Skype and videoconferencing, business travelers still appear to prefer face-to-face contact afforded by travel. Such movement is seen to deepen interpersonal relationships within the organization and with clients. However, research conducted with business travelers by Ipsos MORI for Tandberg in 2006 revealed that motivations for business travel may be rather more multifaceted: over half of European travelers admitted that some of their business trips were unnecessary to their work. Furthermore, 69 percent of those surveyed stated that the enjoyment of experiencing new cultures was the highest rated benefit of business travel, compared to 47 percent who said getting face-to-face with clients was what they enjoyed. Significantly, 15 percent of travelers confided that business travel in fact made them less productive in their jobs. These findings point to the potential for organizations to exploit the ever-evolving non-travel-based communication tools further to meet business objectives more effectively and financially efficiently.

Perceived Risk

Researchers Andrew Lepp and Heather Gibson (2003) have identified seven domains of risk that can affect people's international travel choices: health, political instability, terrorism, strange food, cultural barriers, a nation's political and religious dogma, and crime. Exploring a couple of these further illustrates the insidious ways in which ideas around risk can impact travel behavior.

Security concerns about terrorism, political instability, and crime have increasingly come to the fore with, for example, a recent rise in kidnappings and killings of foreign workers in some African states. This has led to developments such as "no-fly" databases that seek to ensure that all passengers who travel by air are of no risk to other travelers and the aircraft itself and services such as niche security companies for travelers to less developed and greater risk countries. In addition, since September 11, 2001, there has been recognition that aircraft can be used as a weapon for attack on those on the ground.

Public Health Security and Disease

While increased accessibility across nations has enabled the exchange of cultural and social values, there has also been spread of disease associated with such travel. As mobility has provided opportunities, it has also been an enabler of movement of vectors for illness that has seen associated dispersion of illnesses such as SARS, flu, dengue fever, tuberculosis, and malaria across nations and continents. This globalization of health concerns is one of the main drawbacks of travel that crosses national borders. For example, there have been reports that there is an increased incidence of HIV along some of the main international road routes in parts of Africa with evidence suggesting that long-distance drivers may engage in unsafe behaviors facilitating the transfer of the virus. Similarly, the World Bank suggests that seafarers, airline crews, and infrastructure construction workers may also be significant to such spread.

Another transport-related risk to international travelers relates to the incidence of road accidents abroad and the involvement of tourists in accidents. For example, the *New Zealand Herald* reports that in 2012, three American tourists were killed in a crash in May, and four Argentines died in a head-on crash in July. These were among 15 fatal accidents involving foreign drivers that year, which comprised around 7 percent of the total number of fatal crashes. The worldwide road fatality statistics are also relevant to this discussion. Allianz has compiled statistics that show, in absolute numbers the countries that, respectively, have the highest risk of death from road accidents: (1) India, (2) China, (3) United States, (4) Russia, (5) Brazil, (6) Iran, (7) Mexico, (8) Indonesia, (9) South Africa, and (10) Egypt. Many of these are key tourist destinations, highlighting an often overlooked risk of international travel.

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See Also: International Air Passenger Transport; Recreational Travel; Tourism.

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International Waters

International waters can be classified as waters to which more than one nation has rights. These include oceans and seas with international rights of passage or use, lakes, and inland seas with access by more than one nation, rivers and waterways that have more than one riparian nation (transboundary rivers), and transboundary groundwater resources.

Oceans and seas with international rights of passage or use are primarily defined by the United Nations (UN) Convention on the Law of the Sea (UNCLOS). Historically, a nation's waters were limited to what it could effectively control and all others were effectively international waters. This effective control varied with a state's naval power and its ability to control coastal water from shore. Hugo Grotius described this as he laid the foundations of international law based on natural law, and specifically developed the theory of international waters in *The Free Sea (Mare Liberum)* in 1609. Thus, by the 17th century the concept of freedom of the seas was established in theory.

This legal theory was then expanded by the Dutch jurist and legal theorist Cornelius van Bynkershoek in the 18th century. Coastal nations were assumed to have the right to waters up to three nautical miles from the coast (cannon-shot range of the most advanced cannon at the time as calculated by the Italian, Ferdinand Galiani). The concept and limit held except in times of war or by international treaty until the 20th century, when nations argued for rights to the resources found off their coasts.

UNCLOS evolved through a series of negotiations resulting in the first UN Conference on the Law of the Sea, which took place in 1956, and continuing through November 16, 1994, when the agreement entered into force. Negotiations continue to ensure the agreement addresses outstanding and emerging issues.

In *Economic Foundations of the Law of the Sea* (2009), Eric Posner and Alan Sykes point out that UNCLOS has a plausible economic logic:

Jurisdiction over portions of the ocean is assigned to states which can regulate them most cheaply and value them the most. These jurisdictional rights are subject to limits that reflect the interests of other states in navigation and other uses of the seas. For the vast areas of the ocean that no state can regulate, the convention provides for an open access regime subject to simple rules, mostly self-enforcing, to limit conflict over resources.

Thus, UNCLOS divides the seas into zones. Starting with the land, the baseline is drawn at the mean low-water mark and around internal waters. Within this area the nation is the ultimate sovereign and no other nation has rights, even for navigation.

Territorial sea then extends from the baseline seaward for 12 nautical miles. The coastal state may establish laws, use any resource, and regulate the use of resources therein. International vessels have the right of innocent passage and military vessels have the right of transit passage. The contiguous zone extends an additional 12 nautical miles. There the coastal state may exercise the control necessary to prevent the following:

. . . infringement of its customs, fiscal, immigration, or sanitary laws and regulations within its territory or territorial sea; [and] punish infringement of the above laws and regulations committed within its territory or territorial sea.

The exclusive economic zone (EEZ) extends from the edge of the territorial sea to 200 nautical miles from the baseline. Within this zone the coastal state has exclusive rights to exploit all resources. Foreign nations maintain the right of transit or overflight subject to the coastal state's regulations.

The continental shelf is defined geologically and bathymetrically. Where it goes beyond the EEZ, it extends the coastal state's sovereign rights for the following purposes:

. . . for the purpose of exploring it and exploiting . . . the mineral and other nonliving resources of the seabed and subsoil together with living organisms . . . which, at the harvestable stage,

either are immobile on or under the seabed or are unable to move except in constant physical contact with the seabed or the subsoil.

The coastal state's rights may not exceed 350 nautical miles from the baseline even if the continental shelf extends beyond. Foreign nations have rights to navigation, fishing, laying undersea cables, overflights, and research within the limits of other international agreements.

High seas are those areas not falling into one of the other zones, and all nations have freedom of navigation, overflight, lay submarine cables and pipelines, construct artificial islands or other installations permitted by international law, fishing subject to other parts of UNCLOS or other international law, and scientific research.

UNCLOS also addresses the rights of nations to resources and passage under such topics as straits used for international navigation, archipelagic states, islands, enclosed or semienclosed seas, the rights of land-locked states, access and rights to resources, environmental quality, scientific research, the resolution of disputes, and others.

UNCLOS is the primary international legal agreement dealing with international ocean and sea waters. While each U.S. president since the inception of UNCLOS has encouraged its ratification, Congress has not done so. Numerous other bilateral and multilateral agreements exist to address specific issues among specific nations in specific areas.

Inland Waters

Lakes and inland seas accessed by more than one nation are another form of international waters. Enclosed or semienclosed seas are addressed by UNCLOS. These are defined as the following:

. . . a gulf, basin or sea surrounded by two or more States and connected to another sea or the ocean by a narrow outlet or consisting entirely or primarily of the territorial seas and exclusive economic zones of two or more coastal States.

In those situations, coastal states shall work directly with each other or through the appropriate regional organizations to do the following:

. . . coordinate the management, conservation, exploration and exploitation of the living

resources of the sea . . . the implementation of their rights and duties with respect to the protection and preservation of the marine environment . . . their scientific research policies and undertake where appropriate joint programmes . . . [and] to invite . . . other interested States or international organizations to cooperate with them . . .

In other instances of inland water bodies, the management of the international waters is by agreement between the coastal states and may pre-date UNCLOS. For international freshwater bodies there is no overall binding agreement as with oceans and seas. The agreements on conservation, development of resources, navigation, environmental maintenance and other sound use are codified in bilateral or multilateral agreements.

Rivers and waterways that have more than one riparian nation (transboundary rivers) include 263 river and lake basins that cover nearly half of the world's land area. One hundred forty-five nations include at least one international basin and 21 nations lie entirely within an international basin. The United Nations points out the following:

While most basins are shared between just two countries, there are many basins where this number is much higher. There are 13 basins worldwide that are shared between 5 and 8 riparian nations. Five basins, the Congo, Niger, Nile, Rhine and Zambezi, are shared between 9 and 11 countries. The river that flows through the most nations is the Danube, which travels within the territory of 18 nations.

For instance, throughout Europe and western Russia, rivers are connected into an international waterway suitable for navigation. In 1992, the Rhine–Main–Danube Shipping Canal was finally completed linking the North Sea to the Black Sea. In 2002 the Russian waterways became part of the European inland waterway network, thus connecting the Caspian Sea, Black Sea, Mediterranean Sea, Atlantic Ocean, North Sea, Baltic Sea, and Barents Sea by inland water routes. Not only is this inland water system an important engineering feat, it is a major feat of diplomacy and international and domestic policy linking nations physically, economically, and socially. A major problem, however, is that the route also transports invasive biotic species

throughout Europe and western Asia and is a route for chemical pollution transport as well.

Management of major international waters is usually coordinated through river basin commissions or other coordinating bodies such as those on the Nile River, Mekong River, or Saint Lawrence Seaway, and many others.

Groundwater Resources

Transboundary groundwater resources, while generally not navigable, are of major importance, particularly where irrigation is important or where ground water resources are abstracted for domestic consumption or other use requiring maintaining water quality. Like river basins, underground water bodies are not subject to political boundaries so often they are of concern to two or more nations that overlay or otherwise depend on the same resource. The two major concerns are pollution of the groundwater resource and over-abstraction by one nation depleting the water available to another overlaying nation. There is no global agreement pertaining to aquifer management, though principles have been established within the water management community for acceptable practices.

This issue will increase in importance as population grows and economic condition of the population increases, resulting in greater demand for higher quality, water-intensive foods, and demand for irrigation increases due to environmental changes and increasing food demand.

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See Also: Inland Waterways Operations and Management; Maritime Industry; Ocean Cruise Industry; Ocean Passenger Travel; Ships.

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Intersections

Intersections are places on the roadways where two or more roads intersect. They are located on federal and state highways, country roads, and city streets. Intersections differ based on traffic control and on road design, but regardless of their differences, they were the sites of about 40 percent of the estimated 5,811,000 motor vehicle crashes that occurred in the United States in 2008. Between 1998 and 2007, 9,032 deaths each year, on average, were attributable to intersection crashes. These numbers are significant enough to make intersection safety a major priority for national, state, and local governments. The modern roundabout, a type of circular intersection, has been gaining popularity in the United States as an effective means of improving safety, traffic flow, and aesthetics.

Types of Intersections

Uncontrolled intersections are junctions without signs or traffic signals. Right-of-way belongs to the vehicle on the main road in three-way intersections, to the vehicle on the right in four-way intersections. Controlled intersections are marked by signals, traffic signs, or roundabouts. Despite the clarity of rules of the road governing controlled intersections, more accidents occur at these sites. According to a report from the National Highway Traffic Safety Administration (NHTSA), in an estimated

787,236 intersection-related crashes in 2008, about 52.5 percent (413,140) that were assigned a critical reason were traveling on roadways that were controlled by at least one traffic signal and 31.3 percent (246,385) by at least one stop sign.

The higher volume of traffic at controlled intersections is doubtless a contributing factor, but so is the number of drivers who are reckless or distracted. One study found that two of five drivers admitted to having run a red light within the past 30 days, and the 2008 NHTSA report found that in 96.1 percent of crashes the critical reasons were attributed to drivers. This includes 55.7 percent (438,194) drivers with recognition error (inattention, internal and external distractions, inadequate surveillance, etc.) and 29.2 percent (230,047) with decision errors (too fast for conditions or aggressive driving, false assumption of other's actions, illegal maneuver, and misjudgment of gap or other's speed).

Controlled intersections can present hazards for pedestrians and bicyclists too. Six percent of urban bicycle-motor vehicle collisions are related to these users not being able to finish crossing an intersection before the opposing traffic is released. Pedestrians—particularly children, the elderly, and the disabled—may also find it difficult to cross in the allotted time. The 2009 *National Manual on Uniform Traffic Devices* proposed a reduction from 4 feet per second, a common crossing time, to 2.8 feet per second.

Based on road design, the most common type of intersection is the four-way intersection where two roads cross. T-intersections occur when one road dead-ends into a through road. Generally, the minor road at a T-intersection is controlled by a stop sign that directs the driver to wait until the major road is clear before proceeding. A Y-intersection also has three legs, often appearing as if two roadways merge to form one. Such roads may be marked with stop signs on all roads. Occasionally, an intersection has five or more intersecting roads. A six-way intersection involves the crossing of three streets, most often two perpendicular streets and a diagonal street. More than six roads intersecting is rare. A roundabout is an intersection that merges traffic from multiple roadways into a circle. In the United States, traffic moves counterclockwise.

Safety Issues

Based on the Fatality Analysis Reporting System data, an estimated 2,307,000 crashes occurred at

intersections across the country in 2008. Among these, 7,421 were fatal crashes, and in 733,000 crashes, one or more occupants suffered injuries. About 36 percent of these crashes involved people turning or crossing an intersection. Left turns were particularly hazardous, accounting for more than one-fifth of crashes, compared to 1.2 percent of right-turning vehicles. Several studies have been conducted with an in-vehicle warning system for failure-to-obey (running a stop sign or stop light) violations that uses visual, auditory, and brake pulse cues to warn drivers. Participants who did not use the system made three times the did-not-stop errors that participants using the system made. The implications are particularly positive for drivers 65 and older, who are over-represented in intersection crashes and the fastest growing segment of the U.S. population.

Angle crashes at intersections, a particular problem at T-intersections, are among the most severe of intersection crashes. Often limited stopping-sight distance and/or driver failure to judge gaps in opposing traffic are identified as the cause of such crashes. A Colorado experiment installed continuous green T-intersections (CGT) at two rural T-intersections to reduce angle crashes due to left-turning traffic. In CGTs, the main line through traffic passed through without stopping (the top side of the T), obeying a continuous green signal. Dedicated acceleration and deceleration lanes provided for left-turning movements. Concrete median and pavement markings provided lane separation. The results were encouraging: a 96.8 percent reduction in angle crashes per year, a 70 percent reduction in injury crashes per year, and a 60 percent reduction in total crashes per year. Several states, including Colorado, Florida, Maryland, North Carolina, and South Carolina, have converted from fully signalized to continuous green T-intersections to improve safety.

Traffic Circles and Roundabouts

Traffic circles, which are circular intersections where traffic is forced to move around a central island in one direction, were popular in the United States in the first half of the 20th century. In some places, traffic entering the circle has the right-of-way; in others, entering traffic is required to yield. Either way can create delays and congestion. The first traffic circle in the United States may have been Columbus Circle in New York City, built in 1905. Washington, D.C., has more than two dozen. But high numbers of crashes



A sign warns drivers about the shape of an upcoming intersection in the city of Maribor, Slovenia, in 2013. In the United States, as many as 40 percent of all motor vehicle accidents take place at intersections.

and increased congestion had traffic circles falling into disfavor by the mid-1950s.

Modern roundabouts are also circular intersections, but they avoid the problems that led to the decline of traffic circles. The roundabout slows entering traffic and allows all the traffic to flow through the junction freely and safely. Entering vehicles must yield the right-of-way to vehicles already in the circle. Traffic signals are not used, and pedestrians cross the streets at marked crosswalks. Delays are about 50 percent of the average delay imposed by a traffic signal. Aesthetically pleasing, they also improve safety and efficiency for pedestrians, bicyclists, and motor vehicles. Roundabouts have been built in California, Colorado, Florida, Maryland, Missouri, Nevada, Ohio, and Vermont.

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See Also: Bicycle Safety; Highway Interchange and Ramp Design; Highway Interchanges; National Highway Traffic Safety Administration; Pedestrian Safety; Traffic Safety.

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Interstate Commerce Commission

When the U.S. Constitution was written in 1787, the need for establishing guidelines for regulating commerce among the states was clearly in the minds of the nation's founders. Article 1, Section 8, which came to be known as the Commerce Clause, established the power of Congress in the field of interstate transportation by stating that the new national legislature should have the power "to regulate Commerce with foreign Nations, among the several states, and with Indian Tribes." It took another century, however, for Congress to pass the Interstate Commerce Act, which created the Interstate Commerce Commission (ICC) and established the right of the federal government to regulate the railroad industry. This action was designed to maintain fair pricing in both passenger and freight services. Congress further strengthened the powers of the ICC in the early 20th century, with passage of the Hepburn Act and the Mann–Elkins Act. In 1935, Congress passed the Motor Carrier Act, giving the ICC the right to regulate the trucking industry. Subsequently, the ICC was charged with regulating other aspects of interstate commerce, exercising

oversight over interstate bus lines, telephone companies, oil pipelines, freight forwarders, transportation brokers, and express agencies. During the 1970s and 1980s, the move toward deregulation of the transportation sector resulted in an erosion of ICC power. Congress officially abolished the agency in 1995 and transferred most of its responsibilities to the Department of Transportation (DOT).

History

When the Civil War ended in 1865, the United States entered the Industrial Revolution with a vengeance. Thus the time was ripe for the railroad companies to emphasize profits and growth as they increased operations and expanded westward. The railroads had already formed monopolies in their designated areas, but increased industrialization led them to become fiercely competitive. Because public feeling against railroads was so intense, in 1871 Illinois became the first state to try to rein in railroads by regulating their activities within the state. Other states followed suit.

Only Congress had the power to regulate commerce that crossed state boundaries, however. Thus, the Interstate Commerce Act of 1887 gave the Interstate Commerce Commission the right to ascertain that prices set by the railroads were equitable. The ICC was the first independent regulatory agency created in the United States, and it became a model for those that followed. The ICC was initially composed of five members appointed by the president of the United States and confirmed by the Senate. That number increased over time. In order to guarantee objectivity, ICC members were banned from holding any financial interests in the industries they regulated. Despite having considerable authority, the ICC was weakened by the fact that it lacked enforcement power.

In the early 20th century, Congress attempted to strengthen the Interstate Commerce Commission by passing the Hepburn Act of 1906, which allowed the ICC to change railroad rates if those rates had been proven to be unjust or unreasonable during public hearings. Four years later, passage of the Mann–Elkins Act transferred the burden of proof to railroad companies, forcing them to demonstrate the reasonableness of their rate plans. By the 1920s, however, the trend was toward returning authority to railroad companies. Nevertheless, passage of the Esch–Cummins Transportation Act of 1920 allowed the ICC to

oversee railroad mergers and mediate in labor disputes. During this same period, railroads began facing increased competition from trucking companies, which had a good deal more flexibility than railroads in establishing routes. By 1940, the ICC had been given the power to regulate commerce in every field of interstate transportation except aviation.

After the creation of the U.S. Department of Transportation in 1966, the new department took on responsibility for all transportation safety functions. In 1976, Congress passed the Railroad Revitalization and Regulatory Reform Act, which returned more autonomy to individual railroad companies. Trucking companies also gained autonomy in 1980 with passage of the Motor Carrier Act. The Staggers Rail Act of 1980 cemented the move toward deregulation and stripped the ICC of many of its powers. Passing Congress with bipartisan support, the Interstate Commerce Commission Termination Act of 1995 abolished the ICC and created the Surface Transportation Board within the DOT.

Civil Rights

By exercising its regulatory authority over the nation's interstate bus routes, the Interstate Commerce Commission played a major role in the civil rights movement. In 1954, African Americans won a major victory when the Supreme Court handed down the landmark decision in *Brown v. Board of Education* (347 U.S. 483), which mandated desegregation of public schools in the United States. Over the next few years, a series of court cases abolished the "separate but equal" doctrine that had allowed Jim Crow laws to flourish in the south and other areas. However, African Americans were still being discriminated against within the transportation sector. In 1960 in *Boynton v. Virginia* (364 U.S. 454), the Supreme Court held that discrimination on public buses was unconstitutional.

By 1961, membership on the ICC had expanded to 11 members. Ten of those members had been appointed by President Dwight Eisenhower, a conservative, and only one by President John Kennedy, a liberal. On September 22, 1961, the ICC surprisingly responded to a petition from Attorney General Robert Kennedy by unanimously banning discrimination on all interstate buses. Bus companies were ordered to post signs stating that seating was to be carried out "without regard to race, color, creed, or national origin by authority of the

Interstate Commerce Commission." (In 1963 the ICC mandated inclusion of that statement on all bus tickets sold for interstate routes.) The actions by the ICC had major implications for the Freedom Rides, which took place during the summer of 1961. These rides allowed interracial delegations of civil rights activists to test compliance with *Boynton*. Over the course of their bus ride from Washington, D.C., to New Orleans, Louisiana, Freedom Riders were met with violence in cities in Alabama and Mississippi, and the cause of states' rights served as a rallying cry for white protesters.

Closure

At the height of its power, the Interstate Commerce Commission boasted 2,000 employees and operated with an annual budget of \$82 million. After the deregulation that decimated its authority in the first two years of the 1980s, the number of employees dropped to only 400, and the budget was slashed to a mere \$40 million. On December 30, 1995, President Bill Clinton signed the Interstate Commerce Commission Termination Act, officially abolishing the ICC. However, Congress rejected an attempt to abolish the Department of Commerce. The ICC was thus relegated to history after 108 years of regulating interstate commerce.

Within the Department of Transportation, the Surface Transportation Board continues to exercise regulatory power over safety issues and labor disputes within the railroad and trucking industries. Other powers that once belonged to the ICC have been distributed among various departments within the DOT.

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See Also: Deregulation; Freight Rates/Tariffs; Surface Transportation Board; U.S. Department of Transportation.

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Interstate Highway System

The Federal Aid Highway Act of 1938 requested the Bureau of Public Roads (BPR) to compile a report on "superhighways." The report, submitted to Congress in April 1939, proposed a network of interregional highways with connections through and around cities. Section 7 of the Federal Aid Highway Act of 1944 authorized designation of a 40,000-mile (65,000-kilometer) "National System of Interstate Highways." These were the first steps in what became, as President Dwight Eisenhower asserted, legislation that transformed America. It was Eisenhower who took the decisive step on June 29, 1956, when he signed the Federal Aid Highway Act of 1956. Subsequent legislation over the next four decades extended and modified the original act, the same time frame required for the idea of an interstate highway system to be fully realized.

Congressional enthusiasm for the new highway system dimmed when the focus moved to funding. Public excitement was soon shadowed by political battles and social struggles, and activists of future generations would declare the system the bane of civic identity and environmental health. But the 45,012.5 miles of limited-access roads that Eisenhower's dream became would one day carry 21

percent of the country's traffic on 1 percent of its roads and make it possible for a trucker to drive from Seattle to Boston on a single interstate highway in just four days.

The Beginning of the Interstate System

Although it would informally become known simply as "the Interstate," the official name of the proposed system was "The National System of Interstate and Defense Highways." Final changes expanded the system to 41,000 miles (65,983 kilometers) and authorized \$25 billion to be made available in fiscal years 1957 through 1969. The share paid by the federal government would be 90 percent. The money was the sticking point in Congress—no one wanted to pay the bill. The Federal Aid Highway Act of 1956 did not win approval until Representative Hale Boggs (D-Louisiana) of the House Ways and Means Committee, at the suggestion of Secretary of the Treasury George Humphrey, proposed the creation of the Highway Trust Fund, modeled after the Social Security Trust Fund. Revenue from taxes on highway-user products would be credited to the highway fund for use exclusively on the interstate system and other federal-aid highway and bridge projects.

In July 1956, the Bureau of Public Roads (BPR) and the American Association of State Highway Officials (AASHO) collaborated on the design standards. They agreed that the system would consist of divided highways with four or more 12-foot (3.7-meter) lanes. Controlled access would be the rule, with any crossroads moving over or under the routes. All overpasses had to have a 16.5-foot vertical clearance above the freeway, although 14-foot overpasses were permissible within urban areas. This particular specification was included to enable military equipment to pass clearly below an overpass, a reminder that national defense was paramount in the minds of the system's designers. Although military equipment of this size is not commonly transported on the Interstate Highway System, the standard remains. The highways were designed for speeds of 50 miles per hour (mph; 80.5 kilometers per hour, km/h) in mountain terrain, 60 mph (96.6 km/h) in rolling terrain, and 70 mph (112.7 km/h) in flat terrain.

Construction for the AASHO road test, administered by the Highway Research Board, began in August 1956 in Ottawa, Illinois. Financing was provided by an array of agencies and organizations that

included state highway agencies, the BPR, the U.S. Department of Defense, the Automobile Manufacturers Association, the American Petroleum Institute, the American Institute of Steel Construction, foreign countries, and U.S. materials and transportation associations. The 7 miles (11.3 kilometers) of two-lane pavements consisted of 836 test sections in the form of six loops and a straight portion and including 16 short-span bridges. The Department of Defense provided drivers and heavy vehicles for the test traffic, which began operating on October 15, 1958. The road test concluded on November 30, 1960. The test data established the relationships for pavement structural designs based on expected loadings over the life of a pavement.

Before the end of 1956, the first sections of the new system were completed. Both Missouri and Kansas claim the distinction of being home to the first completed section. The Missouri State Highway Commission placed a sign on the Mark Twain Expressway portion of U.S. 40 (future I-70) in St. Charles County, where construction, which included 3.1 miles (5 kilometers) of bridging, grading, and concrete paving leading to a new bridge over the Missouri River, began on August 13. On November 14, 1956, highway officials held a ribbon-cutting ceremony and posted a sign proclaiming the concrete paving of an 8-mile (12.9-kilometer) section of U.S. 40 (I-70) outside Topeka to be the first project completed under the 1956 act.

One of the persistent criticisms aimed at the project throughout its history has been the “cookie-cutter” sameness of the construction. While the design standards were exact, engineers, particularly after the early years, worked with experts from other disciplines and citizens to address environmental and preservationist concerns. One example, the Papago Freeway in Phoenix—the final segment of transcontinental I-10 (Jacksonville, Florida, to Santa Monica, California)—first was to be an elevated highway soaring 10 stories above Phoenix’s Central Avenue. When the structure was opened on August 10, 1990, a below-ground tunnel topped by a long grassy strip called the Margaret T. Hance Park linked the communities on either side of the highway.

The two decades of controversy that delayed the Papago Freeway are indicative of the kinds of problems that had to be resolved before the Interstate Highway System could be completed. Engineers

and steel were sometimes in short supply in the early postwar years, but right-of-way acquisition and the costs of urban routes particularly were problems no one had anticipated. The country was in a recession by August 1957, with unemployment reaching 7 percent and corporate profits reduced by 25 percent by April 1958.

Congress passed the Federal Aid Highway Act of 1958, which increased interstate funding by \$800 million for fiscal years 1959–61 and included an emergency increase of \$400 million for the federal-aid systems in fiscal year 1959. Even with additional funds, by the end of the year, construction expenditures exceeded trust fund receipts. Some feared the collapse of the planned highway system, and congressional critics charged that the states were wasting taxpayers’ money. President Eisenhower requested a temporary 1.5-cent increase in the gas tax, but the Federal Aid Highway Act of 1959 added only a penny (increasing the tax to 4 cents a gallon) through June 1961. But the funding crisis paled in comparison to the battles that were beginning in cities across the nation.

Rebellion in the Cities

By the time Eisenhower left office in 1961, 25 percent of the system (10,440 miles) with a cost of more than \$10 billion was open to traffic, but communities had been destroyed and people displaced in the process. The original plans for the interstate system had largely bypassed major cities, including only short connectors to link cities to the bypass highways. But big-city mayors and business interests lobbied for urban interstate routes, which they saw as a means of revitalizing urban areas and improving property values and thus tax bases. The BPR released a plan late in 1955 that included highway designations for 100 urban areas.

Plans for large metropolitan areas typically included an inner belt road around downtown, an outer belt highway circling the suburbs, and one or more roads connecting the suburbs to the city’s center. The Federal Aid Highway Act of 1956 provided for 6,100 miles of interstate highways through the nation’s largest cities. Later amendments increased urban highways to 8,600 miles, more than one-fifth of the total system.

Eisenhower was convinced that including the city routes had sold the bill to Congress. Inner belts that went around downtown areas meant that

traffic in and out of the city no longer needed to move along city streets. Residential neighborhoods not displaced by the new roads were isolated from the downtown area. Outer belts made travel from surrounding areas into the city's center easy. Since these outlying areas generally offered relatively cheaper land in larger sections, "edge cities" or mid-town sections began to develop.

When the plans were drawn, often as far back as the 1940s, to replace deteriorating homes around the business centers of large cities with an inner belt highway, the population of the displaced area was a racial and ethnic mix. By the 1950s, white flight to suburbia was under way, and the areas of dense traffic flow and cheap land near downtown areas had become populated largely by African American families and businesses. Initially, this population had little effect on route selection of the new highways in the nation's cities, and African American

neighborhoods in Chicago, Miami, New York, and other cities were destroyed.

By the mid-1960s the civil rights movement had changed the political climate of the country. Civil rights struggles had given African American leaders the tools to fight the destruction of inner-city neighborhoods, and organized protests against road construction that was decried as another example of "institutionalized racism" became common. Activists in New York City; Baltimore; Washington, D.C.; New Orleans, and other cities organized to stop construction through neighborhoods. Sometimes the protestors lost. State engineers and local politicians succeeded in building elevated expressways through African American districts in Miami; Baltimore; Indianapolis; New Orleans; Nashville; Columbus, Ohio; and Montgomery, Alabama. But the protests started a change that gained in power as environmentalists added their voices.

The Highway Teardown Movement

By the 1970s, civic leaders in cities such as Portland, Oregon; and Milwaukee, Wisconsin, were heading coalitions of citizens who were pushing to tear down freeways and put cities back together or to provide access again to rivers and lakes blocked by multilane highways. The interstate system that had promised deliverance from urban blight in the beginning was increasingly viewed as a hindrance to urban redevelopment. During the 1980s, groups—many of them public-private partnerships—first conceived of expressway teardowns as opening areas for new forms of economic development, such as waterfront developments, expanded universities and medical centers, new downtown parks, and cultural attractions. During the 1990s, expressway teardowns continued to provide space for such developments. At the same time, environmental concerns moved the national transportation focus from roads to rails.

At the end of the first decade of the 21st century, the Interstate Highway System was plagued by deferred maintenance problems and collapsing bridges. Some cities and states responded by adding to the freeway system. Houston added a third outer beltway; Phoenix planned future highways to accommodate growth over the next four decades; and states, including Maine, Georgia, Alabama, Arkansas, and Nevada, proposed new interstate links. Teardown projects continued to gain impetus in New York City,



A wide swath of Interstate Highway 70 runs through downtown St. Louis, Missouri, as seen from the top of the Gateway Arch. Missouri and Kansas were the sites of the first completed sections of the Interstate Highway System.

New Orleans, and Nashville. Without equaling the politicized revolts of the 1960s, the era that has been termed *post-interstate* seems likely to continue to be a period of clashes between cars and cities and evolving efforts to revitalize the nation's cities.

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See Also: Bureau of Public Roads; Federal Aid Highway Program; Highway Planning; Highway Removal; Highway Trust Fund; Highways, Social and Economic Impacts of.

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In-Vehicle Computers

Automotive marketing research firm AutoPacific lists 65 features available in today's automobiles, that use computers—in addition to the microprocessors used in standard features. Even a new car in the lowest price tier with no extra features is equipped with about 30 computers, and at the other end of the spectrum, every function of a vehicle can be computer-assisted or monitored. In-vehicle computers are used in devices such as Global Positioning System data receivers, satellite radio, drowsiness alert systems, and Volvo's City Safety system, which prevents the car from tailgating.

In-vehicle computers were developed in the early years of the computer industry in the late 1960s and early 1970s, both by computer designers hoping to attract automobile manufacturers as customers and by in-house departments in automobile companies. General Motors, for instance, created the Electronic Control Systems Department in 1971.

Even before the introduction of the first major home computers in the early 1980s, 4-bit microprocessors were incorporated into car designs with cruise control, traction control, and antilock brake control. Other functions followed, made possible by in-vehicle computers: digital speedometers and trip mileage counters, speed warning systems, automatic door locks, and engine control features like ignition spark advance and dwell controls. By 1980, microprocessors were in use to improve emissions systems.

Today, in-vehicle computers are called electronic control units. While early microprocessors used compact, efficient algorithms because of the memory and processing constraints imposed by the technology of the time, systems in today's automobiles may use as many as 100 million lines of code. Some of these systems exist simply to protect against malfunction in other systems, for instance, safeguarding against the effects of electronic interference and preventing sudden braking or acceleration in the event of a system shorting out. This code is sometimes called "defensive programming."

One of the key electronic control units is the engine control unit (sometimes subsumed into a powertrain control module, which also includes a transmission control unit). The engine control unit is responsible for optimizing the performance of a car's internal combustion engine by adjusting the engine's actuators in response to conditions, replacing the older means of using mechanical and pneumatic systems to adjust air/fuel mixture, idle speed, and ignition timing. The idea of an engine control unit considerably predates the use of in-vehicle computers, but it was the use of microprocessors in automobiles that allowed the vision of early engineers to be effectively realized.

Though many manufacturers have proprietary systems in their vehicles, basic descriptive terms tend to describe a class of electronic control units. Airbag control units, for instance, govern the functioning of the airbag feature, while seat control units govern seat functions. Body control modules govern and monitor the electronic systems in the body of the car, from power window and power mirror systems to air conditioning to the immobilizer. The various systems of the car communicate with each other by means of the vehicle bus, which also includes the on-board diagnostics (OBD) connector, required in all American automobiles since 1996. *Bus* in this case is a computing term for a

system responsible for handling data transfers and other functions between systems either within a computer or among multiple computers.

The earliest forms of OBD systems were introduced in the 1980s as the use of electronic control units in cars became more common. When more and more systems are handled electronically and with microprocessors rather than with mechanical parts, the task of identifying the cause of a problem becomes more difficult and one that (barring the source being a broken connection or frayed wire) cannot often be identified through a visual inspection. Further, many of the systems include components that are tedious enough to access that it is not desirable to do so until the mechanic is sure it is necessary. OBD systems diagnose and communicate problems in order to let a mechanic know which component has failed. More recent and sophisticated OBD systems use an industry-standardized system of diagnostic trouble codes (DTCs) in order to identify the exact problem, although without the equipment to access the OBD system, a driver will be notified usually only through vague means like the “check engine” light. OBD is standardized not only in its use of codes but at the hardware level, with OBD-II using a standardized female 16-pin connector as its hardware interface. Other elements of the system are left to the manufacturer’s discretion in order to leave room for reporting information about unique or proprietary systems unique to a particular make or model.

Electronic control units include extensive monitoring systems in order to collect the information needed to let the unit know when and how to respond—by changing gears, for instance, in an automatic transmission, or by turning on a cooling fan to adjust temperature. The vehicle bus is a central network that was introduced as a solution to the growing problem of building physical connections between the various electronic control units that constituted the increasingly sophisticated computer systems of automobiles. Such wiring needed to be custom tailored to each possible configuration of features on each model, making aftermarket additions more complicated as well as often complicating repairs to the electronics. Improvements or new designs also required more extensive testing with this system. A central network, on the other hand, handles communications functions and

is easier to maintain or repair, while also making it much easier to add, remove, or modify features. Signals are transmitted along media ranging from single wires or fiber optics to more sophisticated paired wires in military vehicles where redundancy is even more important.

A wide variety of transmission protocols have been developed; they are the in-vehicle computer equivalent of the TCP/IP protocol used for transmissions on the Internet. BMW, for instance, developed Byteflight, a proprietary vehicle bus protocol that uses both synchronous and asynchronous communications using the time division multiple access (TDMA) standard. Byteflight is a descendent of FlexRay, a protocol developed and used by a consortium of members, including BMW, Volkswagen, Daimler, General Motors, and several semiconductor manufacturers. Though FlexRay disbanded in 2009, the protocol remains in use in, for instance, the BMW 5 Series Gran Turismo, the Audi A6, and the Rolls-Royce Ghost. Mercedes Benz uses D2B (domestic digital bus), which is designed for use with fiber-optic transmission media. Some of the protocols developed for use by automotive computers have since been repurposed for similar use in medical equipment, construction equipment, and automated systems in factories.

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See Also: Automated Vehicle Guidance Systems; Automated Vehicle Location Systems; Automated Vehicle Monitoring Systems; Automobile Accident Avoidance Systems; Collision Avoidance Systems, Automobile.

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Jitneys

Jitneys have long operated in the space between sanctioned public transportation and the private automobile. Jitneys take many forms: vans, cars, shared taxis, minibuses, buses, and even motorcycles. They are operated in numerous ways: semi-fixed routes, fixed routes with variable stops, and complete passenger control over pickups and drop-offs. Initially, the 5-cent fare (known as a “jitney”) was the sole distinguishing feature of the services, but today they often work in cooperative fleets and are highly organized. A brief history of jitneys and two cases are presented here to provide an overview of issues associated with these services.

The precise dates and origins of jitney services are fuzzy. In the United States, the *New York Times* first mentioned the rapid proliferation of jitney services across the country in a January 31, 1915, article titled, “‘Jitney’ Bus Is Taking Many Cities by Storm.” Many accounts trace the origin of jitneys to southern and western cities in North America—most likely somewhere in California—in about 1914, and attribute its development to high levels of unemployment, the novelty of riding in a car, the availability of inexpensive secondhand cars, and advertisements in local newspapers.

Both historically and currently, labor issues with conventional transit have led to increases in jitney operations. For instance, a 1913 streetcar strike in

Phoenix created an opportunity for jitney operators to establish their burgeoning service without competition, and a 1982 transit workers strike in New York City spurred the creation of modern jitney fleets in the city. In the early years, municipalities in the United States and Canada worked hard to curb the creep of jitneys by implementing both reasonable and onerous regulations to protect existing streetcar monopolies and union-organized labor. While such reforms reduced the number of jitneys legally operating, the services remained popular with the public for a variety of reasons. In comparison to fixed-route transit systems, jitneys offered the allure of point-to-point flexibility as paved roads became ubiquitous and automobile transportation became predominant during the Interwar period.

Even though mass motorization dominated North American transport for the last 100 years, jitneys never fully receded into the annals of transportation lore. Unlike capital-intensive, rail-based transportation, jitneys merely require a comparatively inexpensive vehicle and a driver, keeping the barriers to entry for jitney operations relatively minimal.

Jitneys have found eager adopters within segments of urban society. The primary users are those unable to purchase cars or whom public transit serves poorly, namely new immigrants. Over the last 100 years, Americans’ travel habits have changed, but jitneys have retooled along with them. These services have become more organized and

formalized to keep up with the times and to appeal to a new base of consumers. The international adoption of jitneys matches the North American experience, where, once again, the services have grown up in response to high levels of unemployment, declining or nonexistent public transportation, the changing spatial structure of cities, an influx of automobiles, and vast networks of paved roads.

The international context varies considerably from city to city and country to country, but this entry will showcase commonalities by highlighting three key international examples from South Africa, Mexico, and Peru, and two cases from the United States, Chicago and New York. While the root causes of jitney growth differ in the international context—apartheid in Cape Town, insolvency in Lima, and fiscal constraints combined with prodigious road-building in Mexico City—the cases share one key characteristic: the public sector or a private-public transportation monopoly failed to meet the demand for transportation services. Across all cases, it is clear that jitneys emerged when sanctioned providers neglected or lacked the wherewithal to satisfy the public-transportation-riding public.

Development

Dissatisfaction with public transportation, growing cost burdens, shifting demographics, labor strife, and high levels of unemployment unify the international and North American jitney experience. The jitney emerged as a wedge mode of transport for those people in cities who were without access to automobiles or reliable transit. In addition, for those left out of the labor market—this is especially true in apartheid-era South Africa but also for recent Caribbean immigrants in New York and Miami—driving jitneys provided employment where few other options existed.

In the 1910s, the private automobile was still a novelty enjoyed by the elite, and cities were organized around public transportation networks—even though they may have been inadequate. The example of Chicago underscores the mismatch between the capacity of streetcars and the expanding needs of Chicagoans. This is the service mismatch thesis, where Chicago's public transportation riders demanded more "door-to-door" services, like the taxicab, and shorter headway times from streetcar operators. In the first half of this decade, Chicagoans without cars had few options other than

to patronize streetcars and elevated trains, even though public sentiment reflected a growing desire for the point-to-point flexibility of automobiles. A 1915 strike of elevated and surface streetcar operations, however, frayed public perceptions of public transportation and allowed Chicagoans to sample jitneys on a citywide scale with impunity. While the streetcars and elevated railcars survived the strike, riders had been exposed to the advantages of jitneys and taxicabs vis-à-vis their fixed-route competitors.

The experiences of Lima, Peru, share much in common with Chicago's. Much like North American cities, the local government granted concessions to private companies at the start of the 20th century. These concessions granted monopoly status to transportation providers on key routes, while *colectivos*, the Spanish term for jitneys, operated illegally. By the 1950s, many of these sanctioned private bus companies began to file for bankruptcy. The government intervened in 1965, but its plan to roll out of a fleet of 210 buses was inadequate to provide transport service to the rapidly expanding city. The city did not have the financial resources to bankroll an extensive bus network, but the 6,000 illegal *colectivos* were able to provide transportation connections for the vast majority of the public.

Despite the government's attempt to take over public transportation in the 1960s, it was unable to provide the flexibility of routes or frequencies necessary to meet demand. As in the case of Chicago, and really every city where jitneys thrive, the gap between supply and demand provided an obvious point of entry for jitneys in spite of legal obstacles. In sum, the *colectivos* were illegal, but the city depended on their service.

The development of Mexico City's *peseros* shares much in common with jitneys in Lima and Chicago, but this case also highlights the impact of land-use decisions and public investment in infrastructure on public transportation and alternatives. Like Lima, Mexico City underwent intense population growth during the 20th century. Electric trolley service first debuted in 1900 and buses came along 17 years later. The two modes operated side-by-side with both receiving subsidies. To cope with growing congestion, the government widened roads and constructed highways, which in turn opened up more land for development.

During this period of intense growth in automobile use, road building, and regional expansion, the

government also invested in public transportation. In 1969 and 1970, Mexico City introduced three new subway lines. While the government built public transportation infrastructure, it began cutting bus service to conserve money and break the labor union's control over contracts. It was during this period that licensed taxis and jitneys expanded their operations. By 1993, nearly 75,000 *peseros* accounted for more than 50 percent of all vehicle trips in Mexico City. The Mexico City subway remains widely used, but again, the shifting structure of the city favors the flexibility of the minibuses over the subway's fixed route.

The case of Cape Town aligns with many of the general trends identified in the previous examples. Jitneys first emerged in the 1920s, but they were

heavily regulated to protect the railroad monopoly and suppress the expanding black economy. The Group Areas Act of 1950 enforced racial segregation and the construction of black townships beyond Cape Town's Central Business District. While South Africa's economy boomed, the government subsidized the costs of racial segregation, but over time—with an economic crisis in the 1970s providing extra pressure—it became too burdensome for the government to maintain separate infrastructures for white and black areas and to build a road network to satisfy the growing number of drivers.

Because townships were purposely placed on the periphery of the city, public transportation was required to operate over long distances. This, too, eventually became too expensive, and by the 1970s



A taxi park filled with privately operated minibus-taxis in Kampala, Uganda, where they are called matatus. Jitneys frequently develop when sanctioned providers neglect or lack the wherewithal to satisfy those using public transportation. In the example of Cape Town, South Africa, jitneys in the form of minibus-taxis provide 29 percent of all public transportation trips within the city.

and 1980s, the government slashed subsidies for public transportation. The financial strain and spatial fragmentation created the perfect storm for widespread jitney adoption throughout South Africa. In the case of Cape Town, spatial fragmentation, macro-level economic circumstances, and black unemployment spurred the transition from subsidized public transportation to privately provisioned jitneys.

Regulatory Response in New York

Although the adoption of jitneys grew out of genuine transportation needs and, often, government failure, government response to regulating them has been inconsistent. In the North American context, the bulk of jitneys were regulated out of existence in the 1920s. Illegal jitneys continued to operate and reemerged as a vital transportation option in the 1970s and 1980s. The experience of *dollar vans* (a local term for jitneys) in New York is a good example of this phenomenon.

Beyond the United States, the response has also been inconsistent: Governments recognize the utility of jitneys, but their policies have generally been stacked against them. In South Africa, concerns about taxes, public health, and violence have all motivated the government to play a larger role in the industry. The recent rise of bus rapid transit (BRT) in South America, Asia, and Africa has in part been a strategy to clamp down on ad hoc jitney operations and replace them with a formalized BRT system. In South Africa, policymakers have used BRT as an opportunity to cleanse their cities of jitneys altogether. Despite universal governmental intervention, jitneys have proven to be resilient.

New York's story is much like the previous cases examined. Dissatisfaction with public transportation, economic contraction, a lengthy transit strike, and high unemployment contributed greatly to a jitney revival in the 1970s. The municipal government refused to regulate jitneys directly until 1993, when, with the passage of Local Law 115, a legal classification and regulatory regime was established for *commuter vans* (the legal term for jitneys in New York). Local Law 115 defines commuter van service as a "transportation service through the use of one or more commuter vans on a prearranged regular daily basis, over nonspecified or irregular routes."

This definition strips freewheeling jitneys of their flexibility and turns them into another predictable

transportation mode that can be monitored and observed centrally. While Local Law 115 severely limits commuter vans from providing transit-like service, the body tasked with regulating them, the Taxi & Limousine Commission (TLC) lacks the resources to enforce the law. Because the TLC cannot control commuter vans adequately, most flout the law. They do not prearrange rides, they accept street hails, and they pick up passengers at designated bus stops.

Dollar vans have remained vital in New York because they have managed to circumvent regulations and maintain much of the flexibility that made them so popular a century ago—namely semifixed routes and short headways. At the same time, the TLC requires all licensed vans to obtain insurance and submit to routine inspections, and these regulations, unlike the restrictions on street hails, have helped maintain a minimum standard of safety and service without sapping dollar vans of their appeal.

More recently, the dollar vans have demonstrated their value in crises. During transit strikes and extreme storms that have immobilized buses and subways, the dollar vans have come out en masse to pick up fares and transport passengers. During the 2005 transit strike that shutdown New York's public transportation system, dollar vans stepped in and provided service. The role of commuter vans during the 2005 strike highlighted their capacity to provide high-quality public transportation, exposed the failures of Local Law 115, and reinforced the idea that dollar vans contribute a valuable service to New York.

Regulatory Response in Cape Town

The regulatory reaction in Cape Town follows similar trends to the New York case. *Minibus-taxis* (a local term for jitneys) are vital to the city's functioning, but government officials are uncertain of how to make use of the fleet of minibus-taxis that ply Cape Town's streets. While there has been governmental intervention, the results are ambiguous.

Cape Town differs from New York in four important ways: (1) minibus-taxis are the overwhelming public transportation mode of choice throughout South Africa and make up 29 percent of public transportation trips in Cape Town; (2) because of the magnitude of the minibus-taxi phenomenon, regulations come from all levels of government, which creates confusion over precedent and enforcement;

(3) despite being classified as informal, operators and drivers are organized into associations, have their own unions to represent their interests, and organized “taxi ranks” throughout Cape Town serve as important destination points for minibus-taxis; and (4) in recent years, the national government has promoted Bus Rapid Transit as a way of eradicating minibus-taxis and formalizing the sector.

Cape Town differs from other cities in South Africa because it has a well-used commuter rail line. In 2004, there were 1.1 million public transport trips per day, of which 53 percent were served by rail, 29 percent by minibus-taxi, and 18 percent by privately operated but publicly subsidized buses. While Cape Town’s reliance on minibus-taxis pales in comparison to Johannesburg, Cape Town has between 7,500 and 12,500 legal and illegal minibus-taxis providing 332,407 daily rides. Since 1996, ridership has more than doubled from 150,000 rides per day. Government documents estimate that 70 percent of Cape Town’s 565 routes are oversupplied, which causes outbursts of violence among competitors, contributes to congestion, and discourages operators from maintaining their vehicles.

Transportation regulations come from all levels of government in South Africa. This creates overlap, uncertainty, and competing agendas among different agencies focused on different elements of the transportation system. Before 1977, the minibus-taxi industry was completely illegal. As the apartheid-era government began deregulating public transportation, it became increasingly clear that minibus-taxis would play a significant role in the future of South African public transportation.

The 1985 White Paper on National Transport established a quota system to regulate the number of minibus-taxis operating in different parts of the country. In 1987, the South African government sanctioned the use of 16-seat vehicles rather than nine-seat vehicles and further deregulated the industry. The quota system was eliminated, which allowed illegal operators to become legitimate. Since 1995, with the creation of the National Taxi Task Team, the national government has tried to enact policies to encourage greater formalization and control over the minibus-taxi industry.

In 2001, the National Department of Transportation created the South African National Taxi Council to improve negotiations between the numerous

and disparate minibus-taxi operators on policies related to subsidy and regulation. While this has improved dialogue, the industry clings to its outsider heritage and takes enormous pride in being controlled by black entrepreneurs.

In addition to national policies, the city of Cape Town has authority over municipal public transportation, municipal roads, traffic and parking, and municipal planning. While these powers seem straightforward, the overlap between different regulatory bodies and enforcement of existing policies makes it difficult for the city to enact comprehensive plans. In addition, minibus-taxis are privately operated. Thus, regulations determined by the national department of transportation and provincial and local governments also need to be approved by the taxi associations, which are made up of minibus-taxi operators.

A recent effort to convert minibus-taxi permit holders into operating licenses—as a way of weeding out inactive permit holders—has foundered because only 40 percent of permit holders have bothered to acknowledge the policy. The struggle to coordinate with minibus-taxis reduces the effectiveness of other policies, such as the ongoing taxi recapitalization intended to incentivize operators to upgrade their fleet or take a one-time cash payout of 50,000 rand, or about \$6,000, to exit the industry. Without a clear idea of how many minibus-taxis have active permits, it is difficult to allocate enough resources to make the program run smoothly.

Cape Town has been working for several years on its Integrated Transport Plan to consolidate control over the transportation planning functions of the city. The 2006 to 2011 phase of the plan addressed the confusion created by the different regulatory claims made by national, regional, and local entities and argues for the creation of a central transport authority in the city that determines transportation policies.

While different levels of government attempt to coordinate with the minibus-taxi industry, the industry has formed its own structure. The main components of the industry are taxi associations, unions (separate for operators and drivers), owner-drivers, fleet-owners, taxi drivers, queue marshals, minibus-taxi washers, money collectors, and mechanics. Since minibus-taxi operators and drivers have organized themselves and created a robust industry that comprises between 120,000 to

140,000 minibus taxis, they play a significant role in determining regulations. The taxi associations emerged to allocate routes, settle disputes, arrange insurance, secure financing for the purchase of new vehicles, and negotiate with the government.

The emergence of BRT in Cape Town has the explicit intention of optimizing the public transportation network and stripping away the clutter created by the minibus-taxis. While the Cape Town's MyCiTi Integrated Rapid Transit (IRT) system promises to absorb operators affected by the new system if they abandon their minibus-taxi operating licenses, minibus-taxi operators have been slow to give up prized routes and skeptical of governmental intervention. Without good data on ridership, operators' incomes, or the number of vehicles on the road, the government has little information to calibrate incentives adequately. With so much unknown about the minibus-taxi industry, MyCiTi has gotten off to a sluggish start and has been plagued by delays, labor disputes, low ridership, and cost overruns.

Conclusion

Jitneys are informal transit services found in nearly every large city in the world. The services are often overlooked by transport planners and scholars, but they fill gaps in service not covered by conventional transit. In some cases, these gaps are geographic—where jitneys operate no other transit does—and in some cases, the gaps are a result of income or social class. In all cases, jitneys have a long history of operating on the edges of conventional transit services. In many cities, jitneys are lifeline transit service for many, even in cities like New York with vast public transportation networks.

The relative success of jitneys comes from the ease of entry into the market and the demand from riders for more flexible services and routes than public transportation can provide. In many areas, the only barrier to entry is the possession of a vehicle. Yet, even though jitneys are resilient transit service, efforts to formalize jitney services have been difficult. In many North American cities, such attempts have led to degradation of the services. Cape Town provides an example of how jitneys might be used as a feeder within the broader transit system, but, again, there have been problems with implementation that are similar to other attempts to formalize informal transit.

Jitneys remain an important mode of transit for the public, but they are still poorly understood by researchers and policy makers. Minibuses offer great promise for improving the lives of people without access to other public transportation options. Jitneys also can extend the reach of conventional transit by acting as feeder systems. Unfortunately, because jitneys have operated somewhat outside the mainstream, it has been difficult to identify best practices from which policies can be drawn. As a result, jitneys remain a popular and important transportation option with much promise that has yet to be tapped.

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See Also: Bus Rapid Transit; Bus Scheduling; Car Sharing; Employment Location; Latent Travel Demand; Paratransit in Developing Countries; Passenger Van Safety; Shared Taxis; Taxicab Licensing and Regulation.

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Job Access and Reverse Commuting Program

Over the last half-century, employment has sprawled along with the influx of suburban office and industrial parks. The spatial mismatch hypothesis suggests that low-income households have remained in the metropolitan core despite the

suburbanization of employment, resulting in higher levels of unemployment and longer commute times for low-income households. Reverse commuting programs have attempted to break down the geographic barriers that have plagued low-income job seekers since the 1970s but typically suffered from inconsistent usage and a lack of long-term funding.

Low-income people rely heavily on public transit systems because they typically do not have sufficient resources to purchase and maintain cars, but traditional transit schedules and systems are unable to bridge the geographic gap between low-income people and employment opportunities. Public transportation has historically been geared toward moving commuters from the suburbs to the central city. This pattern means that public transportation routes are designed to accommodate greater inbound frequency in the morning hours and outbound frequency in the evening, schedules that operate in the wrong direction to adequately serve low-income people trying to access suburban employment. Low-income people are also hampered by commuter systems that do not meet the needs of workers with nonstandard hours or those who are trip-chaining, meaning that they must make several stops on the way to or from work to take children to school or pick up groceries, for example.

Program Goals

In order to meet the challenges of suburbanizing employment, the 1998 Transportation Equity Act for the 21st Century established the Job Access and Reverse Commuting (JARC) program. In 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users reauthorized JARC as a formula-based program. Designed to rectify the spatial barrier between low-income people and suburbanized employment, JARC has several goals.

First, the program aims to connect low-income residents of central city areas to employment centers in the suburbs. (Low-income people are defined as those who are at or below 150 percent of the federal poverty line.) A second goal is to build interagency collaborations, broadening the potential scope of funded projects. Although narrow transit experiments could possibly produce valuable lessons or solutions, the broader approach can address larger systematic transportation needs. The final goal is to use collaborations

as a mechanism for leveraging local funds and building diverse partnerships.

Funding

The leveraging of local funds is promoted through the program's funding structure. Eligible recipients include state and public entities. Funds are then passed to subrecipients, such as nonprofits, local governments, and public transportation operators. The Federal Transit Administration allocates 60 percent of JARC funds to large urban areas, 20 percent to small urban areas, and 20 percent to rural or smaller urban areas. Local recipients are expected to match federal contributions; the federal portion can be no more than 80 percent for eligible capital and planning costs and no more than 50 percent for operating costs. Ten percent of funds can be used for administrative costs with no required match for this activity.

The eligible uses for JARC funding correspond directly to the programmatic goals. Though subsidizing vehicle purchases for low-income individuals would provide access to employment, car ownership is not an eligible use of JARC funding because it would come at a high cost per person and would be an ineffective means for addressing large-scale transit problems. Eligible uses, therefore, encourage projects that involve mass transit.

Recipients can use JARC funds to extend service times, expand routes, and acquire mapping and dispatch technologies. JARC-funded programs include car loans for shared riders, as well as shuttle, rideshare, and carpool services. A portion of JARC funds can be used for administrative aspects of program implementation, including hiring and marketing. In addition to specifying appropriate uses of monetary allocations, the legislation requires that projects be based on locally developed plans that include both transportation and human services components.

JARC-funded projects have largely met the programmatic goals and consistently followed the guidelines for eligible uses. Many organizations have used JARC funds to develop comparable programs, suggesting that communities across geographies had similar areas of concern. For instance, several entities developed transit services that would allow parents to drop off children at daycare centers or school before work. Other recipients extended hours and routes for existing fixed-route

systems. Both approaches helped users search for jobs and provided access to job training programs, eventually leading to employment.

The implementation of carpooling, mapping, and dispatch software helped improve system efficiency for several communities. At the same time, the localized nature of JARC allowed organizations to develop programs that responded to less common community concerns. One JARC recipient, for example, created an emergency ride home program after users expressed a fear of being stranded at work when their children or families have unexpected needs.

Challenges and Benefits

Recipients generally feel that JARC-funded programs in their communities are successful but not without challenges. One of those challenges is caused by the dispersed geography of suburban employment; while public transit may be able to get employees to a designated suburban station, they may still be several miles from their actual place of work. Perhaps the greatest challenge, scholars have noted, is the complexity of systematic problems that have led to the spatial mismatch, and transit alone is not a sufficient solution to those larger social issues. While transportation can provide access to jobs, reductions in discrimination and segregation are necessary to fully address the entrenched social problems.

Nonetheless, JARC has produced significant benefits. The investment in reverse-commute transportation has the potential to reduce the number of welfare recipients by removing the spatial barrier to employment opportunities. In that way, public transit is a necessary component for reducing poverty and dependence on public assistance programs. Low-income people have cited lack of transportation as a significant barrier to finding and maintaining employment; JARC effectively removes that barrier.

The return on investment is substantial. For every dollar spent through the JARC program, the return is between \$1.50 and \$3.50. The benefits grow over time; over a user's work life, the return on every dollar spent exceeds \$15. The investment results in reduced future costs by increasing employment outcomes. In addition to the financial benefits, JARC allows for the development of new services and collaborations, ensuring

that low-income people have adequate access to opportunities.

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See Also: Federal Transit Administration; Jobs–Housing Balance/Spatial Mismatch; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Spatial Equity Analysis; Transportation Equity Act for the Twenty-First Century.

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Jobs–Housing Balance/ Spatial Mismatch

The concept of spatial mismatch usually refers to the geographical distance between jobs and residences. The phenomenon is a feature of most North American cities, but it can also be observed in other

dispersed or decentralized urban areas. Spatial mismatch is socially and politically relevant because it tends to affect disproportionately the employment prospects of individuals in low-income or ethnic minority communities. The problem is also important for transportation policy because job accessibility depends not only on distance to a job but also on the means of transportation available to the populations living in different parts of the city.

The hypothesis of spatial mismatch has been studied since the late 1960s, usually in the context of North American cities. A large body of evidence points to a high degree of spatial separation between jobs and residences of low-income individuals and ethnic minorities. This phenomenon arises due to a relative concentration of low-income and minority populations in central areas, while the jobs to which they are mostly qualified tend to be dispersed across the suburban landscape. The majority of the studies of this problem have focused on the case of black workers, although there is also significant evidence that other groups, such as the Hispanics, face similar problems.

The problem is relevant because it has been linked to high unemployment rates and low wages.

Distance and travel costs dissuade individuals living in central areas from actively searching for and taking jobs in difficult-to-access suburban areas, reducing their employment choices. Although there is evidence that the same type of job pays lower wages in central areas than in the suburbs, the high commuting costs and time necessary to access suburban jobs offsets the higher pay.

The emergence of the spatial mismatch phenomenon is explained by the population and land use dynamics affecting North American cities since the 1950s, which are characterized by urban sprawl, suburbanization, and dispersion of jobs. The expansion and improvement of the road network and the growth in car ownership rates enabled workers to commute from longer distances. Meanwhile, employers often migrated to suburban areas, too, leading to commuting patterns that varied from the traditional model of commuting from the suburbs to a central location. As these changes have occurred, white people became more concentrated in the suburbs and minorities in central areas.

Spatial mismatch becomes a greater problem when it is compounded by a high degree of spatial segregation of ethnic groups, which is common in



Abandoned public housing units in Buffalo, New York. In the United States, spatial mismatch tends to disproportionately affect the employment prospects of individuals in low-income or ethnic minority communities in urban centers, who may have limited access to suburban jobs. In some countries where residential mobility is controlled by government housing policies, spatial mismatch may instead affect workers living in suburban “new towns” who have limited access to jobs in the city center.

North American cities. Although overt discrimination in the housing market is not permitted by law, it does exist.

In addition, the higher costs of housing in suburbs prevents ethnic minorities and low-income people from moving. Households of the same ethnic groups are also concentrated in central urban areas for social and cultural reasons, because people often chose to live near friends and extended family. Evidence shows that minorities tend to have low degrees of residential mobility and are not as likely to move closer to jobs as whites.

Land use policies, such as zoning, may also have an indirect effect on racial and ethnic segregation, because they affect housing costs and the types of housing available in each neighborhood. The confluence of these factors leads to the stability of spatial segregation across time.

Transportation Availability

The problem of spatial mismatch between residences and jobs relates not only to geographic proximity, but also to the means of transportation available for the population in each neighborhood. For example, studies in many cities show that whites tend to commute longer distances, but blacks spend more time commuting. Realizing that transportation options play a role in job accessibility, some researchers have shifted their focus from the concept of spatial mismatch to that of modal mismatch. That is, they analyze the separation between jobs and residences in terms of access to suitable transportation.

Under this perspective, individuals are at a disadvantage if they do not have access to private transport or if the available public transportation options do not allow them to access areas with high concentrations of jobs at suitable times of the day. The provision of public transportation is, therefore, an important issue for policy-makers to address within the problem of spatial mismatch.

Spatial mismatch is increasingly a characteristic of many cities outside North America, which have gone through a steady process of decentralization and suburbanization, as well. In European cities, new employment centers are often located in suburban areas, near motorway junctions. At the same time, the historical city centers tend to lose population and to be increasingly inhabited by elderly people and racial minorities. However, the

mechanisms of spatial mismatch vary from country to country. In some countries, for example, access to transportation is less of a hindrance for workers than access to residential mobility, which is controlled by government housing policies. A different version of the problem of spatial mismatch has been identified in such cities as Singapore, where workers living in "new towns" in suburban areas have limited accessibility to jobs in the city center.

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See Also: Accessibility and Mobility; Employment Location; Spatial Equity Analysis; Transportation and the Disadvantaged; Travel Patterns by Race/Ethnicity; Urban Sprawl Versus Compact Development.

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Just-in-Time Systems

The primary objective of contemporary capitalism is to increase profits. Thus, over time, manufacturers have developed a variety of techniques to maximize profits. One such technique is the use of just-in-time inventory systems. Through these systems, the ordering of components needed in the manufacturing process is delayed until the last possible moment. By delaying ordering, manufacturers are able to minimize warehouse costs and maximize overall profits.

Early experiments with just-in-time systems date back to the early 1900s, but the concept simply did not take off during that era. The just-in-time

systems utilized by contemporary corporations can be traced back to 1970s Japanese auto manufacturing. The 1973 oil crisis impacted Japan and many other countries negatively and contributed significantly to worldwide recession. Financial hardship forced companies to innovate or perish.

One of the innovators, Toyota, developed just-in-time systems in its automobile manufacturing. When Toyota's use of just-in-time systems enabled the company to outperform their similarly sized competitors, the competitors took notice. Just-in-time systems soon became an industry standard in Asia, and quickly became known in the rest of the world.

Despite the popularity of just-in-time systems with manufacturers, they are not without problems. One of the most hazardous issues is inherent in just-in-time systems: the precision of the last-minute timing of ordering makes manufacturers particularly vulnerable to downstream product shortages. Additionally, such shortages could be, intentionally or unintentionally, exacerbated by conflicts between labor and management. Furthermore, cultural disconnects between the American and Japanese corporate cultures have made it difficult for American facilities to adapt to just-in-time systems developed in Japan. Finally, critics have argued that the presumption of stability inherent in just-in-time systems may be inherently flawed.

How it Works

The aim of just-in-time systems is to remedy perceived inefficiencies in warehouse processes associated with traditional manufacturing. Prior to the development of just-in-time systems, manufacturers were dependent on warehouses during the production process because stockpiles of raw materials and/or components were used to ensure the flow of production. Manufacturers ordered parts at regular intervals to replenish these critical stockpiles. While this practice assured that parts would be available when needed, they required warehouse space and all the associated costs that go with warehousing.

When utilizing just-in-time systems, manufacturers only order parts when existing inventories reach a low point, thus minimizing storage costs. This process relies on signals between different points in the manufacturing process to alert inventory clerks when to order needed parts; thus the

term *just-in-time*. A variety of methods can be used to signal that components need to be ordered, ranging from highly technical inventory systems to simple visual checks.

Proponents of just-in-time systems argue that diminishing storage costs are just the beginning of the savings. Other potential benefits of just-in-time systems include optimizing the flow of production, involving employees in the manufacturing process and associated decision making, and improving the quality of the end product, which will likely increase sales and enhance the reputation of the product.

Just-in-time systems are dependent on a second process called lean production. Without lean production, just-in-time systems may actually harm profitability by slowing production and inhibiting profit through supply shortages. Lean production, at its root, is based on preserving the market value of the product while minimizing excess or inefficient work. All activity must be directed toward definite objectives that add to the value of the end product.

The development of lean production, again, was based on methods developed by Toyota, which identified "seven wastes": inefficient transportation, unneeded inventory, unneeded motion, waiting when value-adding production could be occurring, overprocessing the product, overproduction that creates unneeded surplus, and product defects. By combining just-in-time systems with lean production, Toyota became a manufacturing force. In fact, this combination has since become known industrywide as the Toyota Production System.

Despite the popularity of just-in-time systems and lean production in corporate America, a number of problematic issues have been identified, relating to both human responses to the systems and actual flaws in the assumptions behind just-in-time. At the most basic level, the disconnect between American and Japanese manufacturing culture, which was embedded early in the development of just-in-time systems, led to delays in the implementation of just-in-time systems in the United States.

Another pressing issue is that these types of systems leave consumers and downstream producers open to product shortages in the event of ordering failures at any point in the system. A related, but

equally serious, flaw is that the precision timing necessary for the systems to provide financial savings also makes them vulnerable in the case of labor issues, such as a strike, or industrial sabotage. Well-informed but discontented workers could potentially wreak havoc on the entire production system with only a few well-placed delays in ordering.

In addition to cultural and labor issues, research critical of just-in-time systems and lean production indicates that the reasoning behind the systems themselves may be flawed. In particular, it appears that basing just-in-time systems on the presumption of stability may be faulty.

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See Also: Automobile Industry, Economics of; Freight Handling; Supply-Chain Management; Trucking Industry.

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Latent Travel Demand

Latent travel demand is the increase in travel demand that could be solely attributed to an increase in the transportation system's capacity. An expansion of the existing transportation network, such as the addition of a highway lane, may generate new trips that did not take place in the original system. These new trips represent the latent travel demand.

Rationale

Travel is a derived demand, that is, the demand for travel is an outcome of an individual's demand for some activity, such as work or recreation. Because activities are distributed in geographic space, individuals must travel between various locations to physically access those activities. Individuals make travel choices based on their preferences, available resources, and relative costs. Preferences include attitudes and tastes, for example, bicycling versus walking versus driving.

Travel cost has two components, time and money. Monetary cost is straightforward; it would include a public transit fare or the money spent to own and operate a private automobile. Time cost is not as straightforward because different individuals may value their time differently. Nonetheless, in relative terms, the less time travel takes, the lower the time cost.

To a large extent, the decision to make a trip depends on the cost of making the trip and the benefit or utility the individual would derive as a result of making the trip. For example, an individual may value the trip to work more than the trip to a hair salon. The corresponding cost an individual is willing to bear for making the work trip, then, is likely to be greater than the trip to a hair salon. It is not surprising, therefore, that work trips are usually the biggest part of any individual's travel budget, which comprises both time and money. It follows that the quantity of travel demanded will depend on the cost of travel, all else being equal. For example, an individual may not be willing to travel longer than a certain distance or spend more than a certain amount of money for a work trip, depending on the person's wage rate.

Expansion of transportation network capacity, for example, through the construction of a new highway link, is likely to improve traffic flows, thereby reducing travel times in the short term, especially in a previously congested network. If the monetary cost of travel, such as fuel prices, remains unchanged, then the new highway link would induce new trips solely because of the lower total travel cost, which, in this example, is the reduced travel time. These new trips are said to be the result of latent travel demand because they would not have taken place if the travel costs (in time) were any higher. It follows that in a congested

transportation network, any supply side intervention that reduces traffic congestion will generate additional trips because of latent travel demand, all else being equal.

Measurement

Researchers have often expressed latent travel demand as the elasticity of travel demand with respect to travel cost. An often-used measure for travel demand is the total number of vehicle miles traveled (VMT). VMT is, however, an imperfect measure. For example, trips rerouted over a shorter route, made possible because of a new highway link, reduces the number of miles traveled for all vehicles using the new route.

Travel cost is even more difficult to measure directly. For example, quantifying the time cost of travel is difficult because different individuals value time differently. An often-used proxy for travel cost is the total lane-miles of roadway in any given transportation network, which is frequently used in studies of the effect of transportation network expansion on travel demand.

Lane-miles, again, is an imperfect measure. Although travel time savings is a more appropriate measure, it is very difficult to accurately calculate. In contrast, measuring lane-miles is quite straightforward and can be done with accuracy fairly easily. Finally, an accurate assessment of latent travel demand, or more specifically, induced traffic, is extremely difficult due to the phenomenon of triple convergence. Nonetheless, the available empirical evidence supports existence of positive elasticity of travel demand with respect to network supply, thereby establishing existence of latent travel demand.

Policy Implications

Latent travel demand undermines supply-side interventions in reducing traffic congestion in the long term because additional trips generated as a result of latent travel demand neutralize the benefits of network expansion to a large extent. In theory, these new trips would not have taken place had the expansion not occurred. Hence, supply side interventions by themselves are not considered to be effective long-term remedies for addressing traffic congestion. Rather, transport network expansions should be accompanied by appropriate road pricing strategies to prevent generation of induced

traffic, thereby mitigating traffic congestion effectively in the long term.

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See Also: Derived Demand; Travel Demand; Trip Generation Rates and Models; Triple Convergence; Vehicle Miles Traveled.

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Lead Pollution

A naturally occurring element, lead has been used for more than a century in industrial applications as an ingredient in fuel, paint, pipes and plumbing material, solders, ceramics, folk medicines, and even cosmetics. When manipulated and manufactured, the concentrations of lead in the air and soil can rise to levels unsafe for humans, animals, and the environment. However, because of the auspicious properties of lead—its malleability, nonconductivity, and resistance to corrosion—the substance was used with great frequency until the adverse health effects could no longer be ignored.

Despite widespread evidence of the harm of lead exposure, the manufacturers of some products continue to use lead, and some countries have yet to issue strong regulations against it. Current demand exceeds 10 million tons each year, primarily for leaded batteries and applications such as aviation fuel.

One of the largest contributors to lead pollution, and of particular interest in the context of this volume, was leaded gas manufactured for automobiles. Although the U.S. Environmental Protection Agency (EPA) began limiting the amount of lead that could be used in gasoline in the mid-1970s, it

was not fully phased out until January 1996, when the EPA banned the sale of leaded gas for on-road vehicle use. However, leaded gasoline remained legal for sale when used in off-road vehicles, including airplanes, farm equipment, race cars, and marine engines.

A number of U.S. statutes provide enforcement and regulatory authority to agencies, including the EPA and the U.S. Centers for Disease Control and Prevention (CDC), to regulate, track, and educate the public about the dangers of lead and lead exposure. Such laws include the Toxic Substances Control Act; the Residential Lead-Based Paint Hazard Reduction Act of 1992; the Clean Air Act; the Clean Water Act; the Safe Drinking Water Act; the Resource Conservation and Recovery Act; the Comprehensive Environmental Response, Compensation, and Liability Act; and the Lead Contamination Control Act of 1988.

Most of the world is on track to eliminate the use of leaded gas. In 1999, the World Bank promoted a global phase out of leaded gasoline. By 2011, the National Resources Defense Council announced that over 175 countries had removed lead from gasoline, with only countries such as North Korea, Afghanistan, Algeria, Iraq, Burma, and Yemen failing to ban leaded gas.

History

Leaded gasoline, which *Time* Magazine proclaimed one of the 50 worst inventions ever in 2010, solved a problem that was vexing Charles R. Kettering, the inventor of the self-starting engine. The 1912 Cadillac, produced by General Motors (GM), boasted Kettering's electric ignition, which eliminated the need to hand crank cars. However, drivers of the luxury car were distressed by an engine knocking sound that some attributed to the new starter technology.

Kettering realized the knocking was caused by the fuel, not his device, and he and his colleagues at the GM research laboratories in Dayton, Ohio, experimented with numerous additives to increase the octane level of the fuel and remove the engine knock. In the early 1920s, Thomas Midgley tested tetraethyl lead (TEL) and discovered that small amounts of TEL could do the trick for the power-hungry automobiles in GM's line. Midgley termed the fuel *ethyl gas*, and it became the dominant fuel for the next 50 years.

Both Kettering and Midgely had previously experimented with alcohol and ethanol gasoline blends, both of which had been used in earlier car models. These additives, renewable and nonpolluting, had a fatal flaw in the eyes of GM's decision makers: they were not profitable. GM preferred using TEL, which they also could patent.

Additionally, the CEO of General Motors, Pierre S. DuPont, and his brother Irénée DuPont, CEO of DuPont Company, were able to work together to profit from their exclusive rights to ethyl gasoline, which was advertised with the tagline "ethyl is to gasoline what vitamins are to food."

Ethyl gasoline for the East Coast was initially produced at a Standard Oil refinery in Bayway, New Jersey. Soon, workers at the plant called it the "loony gas building" because of the symptoms displayed by employees who worked closely with TEL, including memory loss, poor coordination, and sudden bursts of fury. Within a single week in 1924, five plant workers died and the majority of the men working with TEL were hospitalized. All told, over 80 percent of plant personnel died or suffered severe lead poisoning. New York City, Philadelphia, and other municipalities banned the sale of leaded gas after the New York City Medical Examiner's Office issued a damning report in the wake of the Bayway deaths.

To avert a national ban, GM and its partners halted sales of ethyl gas and initiated safety studies through the U.S. Bureau of Mines. Financed by the companies, the reports were farcical, with the final authority governing content and release resting with the companies themselves. Although some scientists who were approached by GM to test the ethyl gasoline refused to do so, the chief medical consultant for the gasoline, University of Cincinnati's Dr. Robert Kehoe, proclaimed no health risks were related to the leaded gasoline.

Ultimately, the industry, along with government support, was able to convince the public that leaded gas should remain unregulated. They successfully argued the position that they did not have to prove that ethyl was safe; instead, it was incumbent upon detractors to prove that the ethyl gas possessed dangerous qualities. They maintained that the worker illnesses and deaths were anomalies rather than the inherent result of close contact with TEL. The U.S. government overturned the local bans on leaded gasoline in 1926 and

injunctions were later issued to competitors who questioned the safety of the fuel.

Lead Exposure

In spite of the success of a few large companies in preventing regulation of leaded fuel in the 1920s, lead had been identified as dangerous as early as the Roman Empire. Commentators noted that lead, used by Romans to sweeten wine, deleteriously affected those who inhaled its fumes. In 1700, Italian physician Bernardo Ramazzini remarked that miners who worked with lead experienced what we would now label hallucinations or psychotic episodes. Benjamin Franklin and Charles Dickens both cautioned the public against the dangers of lead exposure. In the early years of the 20th century, physician Alice Hamilton studied lead poisoning among Illinois laborers and advocated for greater worker protection.

Over the ensuing century, lead has been identified as a toxic substance. Government agencies, including the National Institutes of Health (NIH), state that no amount of lead exposure is safe. For children, who are more susceptible to the ill effects of lead exposure and lead poisoning, the CDC advise that any child with a blood level of lead of more than 5 micrograms per deciliter should be considered at risk and that public health actions should be initiated.

Adults suffering lead poisoning experience decreased kidney function, disruptions of the reproductive system, decreased nervous system performance, cardiovascular distress, mental impairment, miscarriages, abnormal fetal development or premature birth in pregnant women, and death. The health effects of lead on children include decreased IQ, decreased academic achievement,



U.S. Environmental Protection Agency staff members collect water sampling devices surrounded by floating booms in the Lower Duwamish Waterway Superfund Site in Seattle, Washington, January 15, 2013. This waterway is seriously contaminated with chemicals from industry as well as from runoff from nearby streets and roads. As many as 1,272 of the 1,684 sites on the EPA's National Priority List of Superfund sites are contaminated with lead.

increased incidence of attention-related behaviors and behavior problems, reduced postnatal growth, delayed puberty, and hearing loss.

Researchers conducting a 300-person longitudinal study in Cincinnati, Ohio, found that exposure to high levels of lead in childhood impaired the development of the myelin sheath in the nervous system and destroyed prefrontal gray matter in the brain's cortex.

Some researchers, beginning in 2000 with Rick Nevin, an economist with the U.S. Department of Housing and Urban Development, have proposed that lower crime rates recorded in the United States since the 1990s were a result of the ban on leaded gas that started in the 1970s. Nevin and other scientists have investigated the correlation between crime statistics and bans on leaded gasoline and have seen similar results in various national, state, city, and international contexts. Research commissioned by the United Nations Environment Programme found that 58 million fewer crimes and 1.2 million fewer premature deaths have occurred because of the elimination of leaded gasoline.

Moving forward, the task remains to reduce the use of lead in other industries. Lead does not break down naturally. It can travel many miles by air and attach to soil particles. In some cases, lead travels to and contaminates groundwater. Lead had been found at 1,272 of the 1,684 sites on the National Priority List of Superfund sites identified by the EPA.

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See Also: Air Pollution/Air Quality; Airports, Environmental Issues and; Environmental Impacts; Environmental Justice; Gasoline, Reformulated; Health Issues; Mobile Emissions; Vehicle Emissions Standards.

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Levels of Service

Levels of service (LOS) is a set of performance or service-quality categories used in transportation planning. A system with six levels, ranked from A to F, was first published in 1965 in the *Highway Capacity Manual* published by the Transportation Research Board in the United States. The LOS concept has become a de facto standard in many other transportation contexts and is used for planning, to evaluate present road and traffic conditions, and to estimate the results of proposed changes such as widening roads.

LOS is a valuable tool for planning, particularly in the context for which it was originally developed—that of freeways—but applying the LOS concept in other contexts, such as urban areas, has been criticized as inappropriate.

Automobile Travel

In the six-letter LOS scale, each letter represents a range of conditions, representing the traveler's point of view. Level A represents the best operating conditions, with the lowest density of automobiles and high travel speeds, and Level F the worst, with highest density and slowest travel. Determining a level of service requires complex calculations regarding information such as service density

(defined as passenger cars per mile per lane), traffic speed, and flow, and the alphabetic system is meant to be a simple way to convey this information to the public. (Details about calculations are available in the *Highway Capacity Manual*.)

For freeways, Level A describes traffic that flows freely, at a high speed, and with density low enough that one car is not affected by another; for instance, it is easy for a driver to change lanes. At Level B, traffic flows freely and at a high speed, but drivers must be more aware of the presence of other cars when maneuvering. At Level C, drivers are highly influenced by the presence of other automobiles, so lane changes can be difficult, and a lane blockage can lead to a significant delay. At Level D, the flow of traffic is sufficient to force decreased travel speeds, maneuvering in traffic becomes difficult, and even a minor lane blockage can cause a significant delay. At Level E, operation is at or near capacity, and maneuvering is difficult. At Level F, traffic demand exceeds capacity, and cars are subject to stop-and-go driving or gridlock.

Other Applications

The LOS concept has also been applied in other areas, including bicycle travel, pedestrian travel, and parking facilities. Later editions of the *Highway Capacity Manual* included LOS standards for cyclists, pedestrians, and transit systems, but these have been criticized as being modeled on automobile standards and, therefore, as being overly concerned with traffic flow.

In 1998, Linda Dixon developed standards for pedestrian and bicycle levels of service, using a checklist that assigned points to different aspects of the walking or cycling environment, which were then added up and the total score was used to determine the LOS. For instance, for pedestrians, if a continuous sidewalk was available on both sides of the street, the area received a score of 6; if a continuous sidewalk was on only one side, a score of 4; and if the sidewalk was nonexistent or not continuous, a score of 0. Presence of shade trees was worth 0.5 point, while the presence of medians received one point, and so on. A total score greater than 17 received a LOS of A, 14.5 to 17 points, B, and the scale continued down to 3 or fewer points, which received a LOS of F. For bicycling, Dixon's checklist included factors such as lane width, unrestricted sight distance, and the maintenance condition of

the roadway. The same A-to-F scale was applied to the total score.

In 1996, Mary Smith described LOS for parking structures. Rather than a one-size-fits all scale, Smith suggests applying different criteria depending on characteristics of various users of the facility and the likely priorities of different user groups. For visitors who are unfamiliar with the facility, she suggests valuing Level A service based on factors related to the freedom to maneuver (for example, ramp slopes and turning radii) and flow capacity but placing lower priority on travel time within the facility. In contrast, she suggests that drivers who use a parking facility on a regular basis are more likely to be concerned with travel distance and wait time at entry and exit points. Such users would prefer Level A service in those categories but would be less concerned with factors related to freedom to maneuver, where they might accept Level D service.

Criticisms

LOS was developed during a period of expanding freeway construction, and the metric is based on the principle that freely flowing traffic is good and congestion is bad. It is not mandated for use in other applications but is often accepted as a de facto standard for all types of streets and multiple modes of transport.

In 2012, Gary Toth criticized the automatic application of LOS standards to urban areas, where movement patterns are not necessarily optimized for free traffic flow. In such areas, the standard is usually to have sufficient capacity to meet a C- or D-level LOS. He makes two related points: one is that free-flowing automobile traffic may not be a logical goal for an urban area; the other is that achieving easy traffic flow may require too high a price in terms of safety, quality of life, and other factors in the area.

He points out that the purpose of an urban street is not merely to move traffic—although that is clearly the main purpose of an interstate highway—but, rather, that the street forms part of people's living and working space. In the urban context, he argues, congestion is not necessarily a bad thing, and projects such as street widening, which would limit space for crosswalks and pedestrian access, make an urban area less desirable for the people who live there.

Another, more general, criticism of LOS is that it is applied as a single national standard, without accounting for local differences in how people view

traffic issues. This includes not only rural-urban differences in how streets are used, as cited by Toth, but also regional differences and preferences. Perhaps people in North Carolina are more willing to accept slower traffic flow than people in Maryland, for instance, or Chicagoans would accept a wait time at a traffic light that would be rejected as unreasonable in Atlanta.

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See Also: Highway Finance; Road Pricing Schemes, U.S. and International; Traffic Engineering; Traffic Flow.

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Light Electric Vehicles

A light electric vehicle (LEV) is a land vehicle propelled by an electric motor that uses an energy storage device, such as a battery or fuel cell; has two or three wheels; and typically weighs less than 220.5

pounds (100 kilograms). LEVs range from the Segway personal transporter to power-assisted wheelchairs, one-person cars, personal rapid transit, and pedicabs (rickshaws), but the most common LEVs in the United States are electric bicycles and scooters.

LEVs are clean, efficient vehicles that save time and money and earn praise for their environmental friendliness. Despite these advantages, they remain a niche product in the United States. Some advocates insist the market will change in the future, an argument that gained weight in spring 2013 when Toyota introduced the i-Road Concept at an automobile show, promising 70 models in 2014.

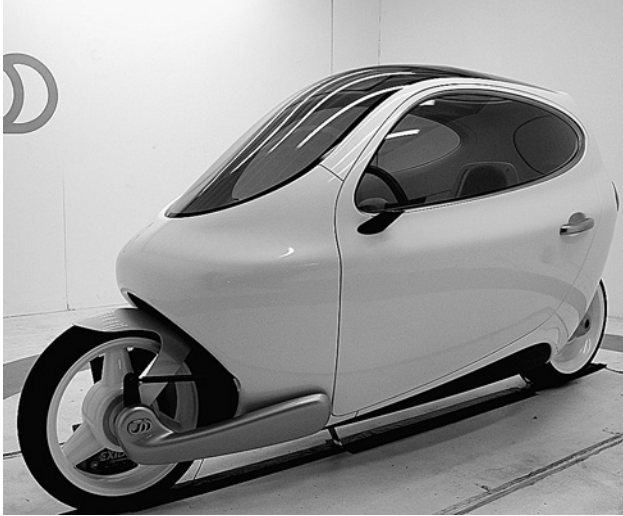
The Segway

On December 3, 2001, the Segway Human Transporter was introduced amid much fanfare on ABC's morning news program *Good Morning America*. The Segway's creator, Dean Kamen, predicted that the LEV would change the world, quickly navigating city streets, easing congestion, and lowering pollutants. One investor publicly predicted sales of \$1 billion, and high-profile investors such as Amazon.com chief Jeff Bezos and Apple's Steve Jobs lent credence to the claim.

But, by 2010, only about 80,000 Segways were in use worldwide, and *Time* magazine named it one of the 50 worst inventions ever. Later the same year, the death of company owner Jimi Heselden, after falling from a cliff while riding his Segway on his British estate, garnered headlines around the world. Ironically, the tycoon's company had only acquired Segway in December 2009. In December 2010, a student who suffered a traumatic brain injury when he fell during a Segway competition won a \$10-million verdict against the company. Segway was bought by Tennessee-based Summit Strategic Investments in 2013. Summit promised expansion and the release of new products.

Electric Scooters and Bicycles

Once a toy for children, electric scooters have been adopted by adults as an economical and emissions-free method of personal transportation. Some are designed primarily for campus travel; others are used on city streets. Between 2007 and 2008, the number of scooters on city streets in the United States increased 200 percent. As of 2012, there were more than 1 million of them in the United States. A wide selection of electric scooters



A two-wheeled C-1 electric vehicle built by Lit Motors. The C-1, which is expected to sell for \$24,000, can reach speeds of up to 120 mph and travel 200 miles on a single charge.

is available, with speeds starting below 10 miles per hour (mph) and reaching up to 30 mph; they can travel distances ranging from 15 to more than 60 miles, and prices start at less than \$1,000 and top off at around \$9,000.

Electric bicycles are not mopeds or motorcycles. They are bicycles that can either be pedaled in the traditional fashion or with an assist from the electric motor. Commuters in China and Europe use them, contributing to global sales of an estimated 29.3 million e-bikes in 2012 alone, as compared to about 120,000 electric cars sold worldwide. The price makes them attractive. Although a consumer can pay from \$29,000 to \$95,000 for an electric car, an e-bike starts at around \$500 for a basic model, about the same price as a top-of-the-line conventional bicycle. There is a German e-bike on the market, the Blacktrail BT-1, that claims a top speed of 65 mph and retails for \$80,000, but the average, good-quality e-bicycle sells for \$2,500 to \$3,000.

Price differences are moot, however, if no one in the United States is buying. Yet, with U.S. sales estimated at 159,000 units in 2012, the market does appear to be growing. Industry executives point out the increase in the number of Americans biking to work as a harbinger.

According to the League of American Bicyclists, bike commuting grew by 47 percent nationally between 2000 and 2011, and it grew by 80 percent

in communities designated as “bicycle friendly” by the league. Cities from coast to coast and points in between are becoming more bicycle friendly, with New York, Chicago, Washington, D.C., and Los Angeles building dedicated bike lanes.

The industry is targeting two groups: baby boomers concerned about exercise and weight, who are already returning to the bicycle in significant numbers, and urban buyers in their 20s and 30s, with less money to spend than older generations and not as much enchantment with the automobile. For both groups, the selling point for e-bicycles is that they reduce greenhouse gas emissions, air pollution, and traffic congestion.

The LEV of the Future

Despite the dreams of environmentalists and technologists, consumers have failed to embrace light electric vehicles in significant numbers in the United States. Dan Sperling, a professor of civil engineering and environmental science and policy at the University of California, Davis, and director of its Institute of Transportation Studies, sees the high cost of batteries for LEVs as the sticking point. While the technology in computer chips and digital storage has improved as they dropped in price, batteries have remained bulky and expensive.

Small startups and global companies alike are working to deliver affordable and practical vehicles to the mass market. Lit Motors, a company with a staff of 10, plans to introduce in 2014 the C-1, a cross between an electric motorcycle and a car with a top speed of 120 mph and the ability to travel 200 miles on a full charge. The vehicle, which will sell for \$24,000 for the first production run of 1,000, targets motorcyclists between 45 and 60 years old who are concerned about safety but don't want to give up their two-wheeler, and younger commuters who live in urban or suburban areas where driving a car may be less attractive. According to the *New York Times*, as of October 2012, about 250 people had already preordered the vehicle.

Toyota's i-Road Concept, introduced at the 2013 Geneva Motor Show, is powered by a lithium-ion battery paired to two 2-kilowatt (2.7-horsepower) electric motors driving the front wheels. According to Toyota, charging the i-Road should take about three hours using an ordinary 120-volt household power outlet. At 660 pounds, the i-Road is considerably heavier than electric bicycles and motorcycles,

and its top speed is only 28 mph, but Toyota is counting on it making up for what it lacks in speed in efficiency and environmental friendliness.

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See Also: Bicycles, Electric; Environmental Impacts; Greenhouse Gases; Motorcycles; Personal Rapid Transit; Personal Transportation Systems.

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Light Pollution

Light pollution, which is excessive and misdirected artificial light, has become a serious threat to human health and the environment. It causes damaging effects on people and their habitat and also wastes billions of dollars and vast amounts of energy from unnecessary lighting.

Transportation both contributes to and is impacted by light pollution. Headlights, street lights, aviation lights, railway lights, and lighted signs for roadways and railway stations are just a few examples of how transportation systems feed artificial light into the environment. Although the environmental effects of transportation are supposed to be considered in all cases, civil engineers for many years have overlooked the impact of light pollution.

Environmental Problems

Human beings naturally derive their sleeping and waking schedules based on the rising and setting of the sun. For wildlife, too, natural rhythms and activities are tied to sunlight and darkness. Excessive light at night interferes with many necessary

activities for wildlife. Nocturnal creatures, in particular, are at risk because they no longer have the cover of darkness to protect them from predators or the natural signal that it is night and time to become active.

At the same time, much of the artificial light is not used for any purpose. Roughly one-third of all light pollution is wasted energy, which uses up 30 million barrels of oil and 8.2 million tons of coal each year at a cost in the United States about \$2 billion, according to the International Dark-Sky Association. In addition, the oil used emits nearly 14.1 million tons of carbon dioxide (CO₂) into the environment, which contributes to global warming.

Light Trespass

Light trespass is a form of light pollution that occurs when artificial light interferes with a person's normal dark cycle. Bright days and dark nights are essential for proper sleep cycles. For instance, streetlights or car headlights that spill over into one's backyard is considered light trespass. To combat light trespass, it is ideal to have artificial street lighting specifically directed at the roads, not at the surrounding residences.

Glare is a form of light pollution that directly impacts a person's eyes. This is regarded as the most dangerous side effect of light pollution. There are three different types of glare: blinding glare, which is so severe that the eyes cannot adjust to the darkness for some time even after the light source is removed; disability glare, which reduces visual performance; and discomfort glare, which, although it may not interfere with person's performance, creates annoyance and distraction. Discomfort glare is common for drivers on roads where they are not protected from the headlights beaming from cars traveling in the opposite direction at night.

Another form of excessive artificial light is referred to as clutter. When too many lights are placed in one location, the result is not better visual acuity but cluttered light, which is highly distracting, especially for drivers. Human eyes naturally adjust to low lighting and generally adapt well to dark areas. However, overly bright and abundant light prevents eyes from naturally adapting, so that dark areas adjacent to brightly lit areas are nearly impossible to see. Driving along unevenly lit roads at night, therefore, is especially dangerous.



This view of the city of Paris, France, in February 2008, shows how artificial light emanating from a city can scatter into the atmosphere and brighten the natural sky, an effect called urban sky glow. Almost 50 percent of urban sky glow is caused by street lighting. Approximately one-third of all light pollution is wasted energy, which costs about \$2 billion per year in the United States, and consumes as much as 30 million barrels of oil and 8.2 million tons of coal annually.

High-Mast Lighting and Urban Sky Glow

High-mast lighting is a series of tall poles, often greater than 60 feet tall, which point extreme lights toward the ground. These can be found often along highways to aid drivers at night, at stadiums and arenas that hold nighttime entertainment, or parking lots. While some have a circular shield to reduce light pollution, these devices generate great amounts of light, comparable to floodlights, and light pollution is inescapable.

When designing and building a new highway system, the pros and cons of high-mast lights must be considered before they are specified.

Urban sky glow involves all the various forms of artificial light coming from a city scattering into the atmosphere and brightening the natural sky. Street lighting causes nearly 50 percent of urban sky glow. Ninety-five percent of street lighting points toward

the ground, but it is then reflected off various surfaces and dispersed around the environment. Airplanes also cause significant light pollution and contribute to urban sky glow.

Light Pollution Planning and Policy

Of the many environmental impacts of transportation infrastructure, light pollution is widely ignored. Yet, it is the responsibility of traffic and civil engineers to properly manage projects early in the planning stages to identify and find solutions to problems that could be caused by lighting.

Researchers estimate that upward of 50 percent of all light pollution may result from roadway lighting. Overuse of artificial light not only damages the environment, but also affects wildlife, human circadian rhythms and the aesthetics of the outdoors. Mounting concern about outdoor lighting

has prompted bylaws in both the United States and Canada regarding the design of the lights.

Roadway lighting provides many benefits, of course. It serves as a supplement to headlights to help reduce nighttime accidents, deters crime, facilitates traffic flow, promotes businesses, inspires community growth, and insures safety for pedestrians. The benefits are a result of proper planning, however. If a lighting fixture is of poor quality or design, the light will not fall on the road but onto lawns or into homes. To prevent this light trespass, designers must create fixtures that use luminaires with light distributions that are suitable for the roadway for which they are intended. Calculations must be precise to determine the correct placement of each fixture.

Roadway planners should use energy efficient LED lights rather than halogen lights, which face upward. For the cost, these lights are more efficient for taxpayers and deliver the same safety effect for travelers. LED lights, however, still produce tinted blue lights, which can interfere with human night vision.

Therefore, roadway lighting systems should use energy-efficient, full-cutoff luminaires to control the amount of light emitted. The term *full-cutoff luminaire* refers to one that allows no direct light emission above a horizontal plane through the luminaire's lowest light-emitting part. Designers and planners should also use the most up-to-date principles available to insure that roadways are not overly lit.

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See Also: Air Pollution/Air Quality; Road Dust; Smog.

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Light Rail Transit

Light rail transit (LRT) has emerged as a form of rail transit designed for trips inside a city and/or trips linking suburbs and the urban core. Light rail use has followed the rising costs associated with oil as a fuel source, postwar increases in automobile ownership and resultant congestion, and an increased premium placed on coordinating transit with other planning goals.

New LRT systems developed in the United States because of innovations made by local transit advocates and planning agencies, with inspiration taken from Northern European systems. Cities have chosen light rail as a less costly alternative to subways and in response to real estate interests or residents who want to promote less car-dependent neighborhoods. Often LRT planners seek gains from transit-oriented development or by linking transit and growth goals to support central business district (CBD) development.

Not all regions have been equally successful with LRT. Regions with the greatest success in attracting passengers and transit-related growth have made planning decisions to tie LRT to increasing urban density and have located light rail near transportation focal points. Studies comparing LRT to other transportation modes have noted LRT's advantages in speed, cost and sustainability, but some researchers have also taken issues with various claims.

Definition

LRT is a public transport system that uses steel-tracks on a fixed guideway, generally operating using exclusive rights of way and vehicles that can operate as multiple units coupled together or as single units. Sometimes LRT tracks can overlap with city streets, sharing traffic with cars and other vehicles. Light rail systems are usually at surface level, but they sometimes operate within systems with underground, or subway, stations and sections. For example, about 80 percent of Buffalo, New York's LRT system is underground.

Although heavy transit systems—popularly known as subways, metros, or undergrounds—generally have greater operating speeds than LRT systems, the LRT can save passengers time through reduced boarding and exiting times, and stations can be closer to destinations, leading to shorter commuting times. Planners must decide between

having more stops, which provides better access to buildings and homes in dense downtown areas, or fewer stops, which decrease total commuting time for those living in outlying areas.

A variety of different specific technologies are being used by different LRTs around the world. In Portland, Oregon; and Boston, Massachusetts, a part of the system involves underground stations. In both Portland, Oregon; and Stockholm, Sweden; the light rail system interfaces with street traffic in some areas, even though each system primarily travels on a dedicated right-of-way separated from street traffic. In the United Kingdom, the Docklands Light Railway (DLR) in London is a fully automated system with cars powered by an electrified third rail, a power source usually used by traditional heavy rail systems.

The Rise and Fall of the Streetcar

In the *Light Rail Developers' Handbook*, Lewis Lesley compares light rail to streetcars and traces them back “to medieval mines in Europe, where beams of wood were laid longitudinally to make the haulage of wagons easier. These “traams” or wooden balks lent their name to tramways. Later, iron plates were used on the timber beams to increase life and give a smoother haul, and with the advent of iron rails and steam haulage came railways.”

Lesley states that the birth of light rail can be dated to 1832, when the first street railway was laid on 8th Avenue in New York City. Urban streets in those days were then mainly plain dirt that turned to mud in rainy weather. With the addition of rails, the load a horse could pull along those streets was increased eightfold, he notes. Other North American cities developed their own horse-drawn street railways, and the first European system opened in England in 1860.

Starting in the late 1920s, cities began switching from streetcars to buses. The advantages were that tracks no longer had to be maintained, one mechanical failure would not shut down an entire line, and buses were easily rerouted if demand shifted or a street was temporarily blocked by a fire or another emergency. The initial investment cost for a bus was also far lower than for a streetcar.

Although transit companies tended to think about the lower capital investment in buses versus streetcars, the cost of operating buses was actually higher over the long term and they wore out

sooner. While buses needed replacement after only six to eight years, streetcars could easily run for decades.

The decline of streetcars is evident in the numbers. In 1930, there were 55,150 streetcars, 173 trackless trolleys, and 21,300 motorbuses in the inventory operated by U.S. transit companies. In 1960, there were only 2,856 streetcars, 3,826 trackless trolleys and 49,600 buses.

While buses may have replaced streetcars because of their lower capital costs and greater route flexibility, history also includes questions about the role of such companies as Firestone Tire, General Motors (GM), Phillips Petroleum, and Standard Oil of California—all of which had more to gain from the rise of bus transportation than the continued use of streetcars.

During the late 1930s and most of the 1940s, Firestone, GM, Phillips and Standard Oil of California were equity investors in a holding company, National City Lines, Inc., which acquired local transit companies all over the United States, amassing almost 50 systems by 1947. From 1947 through 1949, an antitrust suit, *United States v. National City Lines, Inc.*, moved through various federal courts, including the U.S. Supreme Court, before the companies were convicted in 1949 of creating a monopoly to supply equipment, fuel, tires and other products to the transit systems.

The holding company was dissolved, but by that point, the conversion from streetcars to buses in transit systems was largely complete across the country. Only a few large cities—including Boston, Massachusetts; Philadelphia and Pittsburgh, Pennsylvania; Newark, New Jersey; San Francisco, California; and Toronto, Ontario—continued to operate streetcars. They survived for a variety of reasons, but their success rested largely on their ability to move people much more quickly than any transportation mode using surface streets because of their reserved rights-of-way and tunnels.

Light Rail Renaissance

The public quickly became disenchanted with the buses that mostly had replaced streetcars. In the 1950s and 1960s, buses were characterized by heavy fumes, jerky starts and stops, slow speeds and general lack of comfort. Soon, passengers abandoned buses for automobiles and mass transit ridership declined.

In Europe, the 1970s represented a turning point as cities began to realize the truth behind the seminal findings of British professor Colin Buchanan's 1963 report, "Traffic in Towns." Buchanan found that the potential demand for automotive travel was so great that even in low-density cities, there would not be sufficient road or parking capacity to meet peak travel needs.

In North America, researcher Gregory L. Thompson traces the origins of the light rail renaissance in the late 1960s and early 1970s to Edmonton, Alberta, and San Diego, California, which were the first cities to adopt light rail in Canada and the United States, respectively. He credits the following for the revival:

[v]isionaries and reformers who, because of globalization, were able to look past the domestic transit industry and its suppliers to more promising offerings from the transit industry in northern Europe.

Thompson writes that a "growing disillusionment with technological progress" and an attempt to move beyond the status quo in transit services led to the emergence of a "light rail movement." North European cities made several innovations, among them the use of large cars with wider doors to handle greater numbers of passengers, enhancements that led to greater rail-car speed, and traffic engineering and infrastructure investments that supported railway development.

Portland, Oregon, became a model for many planners. In 1978, the city banned passenger cars from a 12-block area connected to the two main downtown thoroughfares, thereby encouraging pedestrian traffic and mass transit use. In 1986, a 15-mile segment of a new LRT between Portland and Gresham, a city 16 miles to the east, opened. In 2001, the city built the first major modern streetcar system in the United States. This line did not travel to distant suburbs. Rather, it used shorter trains and focused on the urban core.

Light Rail, Land Use, and Development

LRT has to be considered as part of a larger environmental, energy, economic, and urban system. The U.S. government has supported light rail projects over the last several decades partly because of the ecological and energy-saving benefits. Mass

transit is seen as contributing to improved air quality and energy conservation. The economic and urban systemic aspects of light rail involve not only its costs but also the relationship of this transportation mode and infrastructure to larger development goals a city might have. LRT planners have usually linked transportation planning to other objectives, although the ability to link these goals differs depending on a locality's philosophy, historical circumstances and resources.

The automobile, cheap gas, and rising land values made possible and promoted decentralized spatial configurations, helping lure businesses and jobs from downtown hubs, particularly in the postwar era. In contrast, older cities had previously followed a hub-spoke pattern connecting various suburbs with a CBD. In the early postwar years, from the 1940s to the 1970s, the suburbs and cities competed for some of the same business patrons. Starting in the 1980s, the revival of many CBDs helped fuel the return of urban light rail systems, which often became part of larger redevelopment efforts.

Thompson and Jeffrey R. Brown studied 10 metropolitan areas with LRT, compiling data looking at CBD employment as a share of regional employment from 1970 to 2000. The employment share for the cities decreased significantly in Atlanta, Dallas-Fort Worth and Minneapolis-Saint Paul, but it increased in Denver, Miami, Pittsburgh, Portland, Sacramento, and San Diego. Salt Lake City showed only a slight decrease.

Even though each of these cities has a light rail system, Thompson and Brown found that the type of LRT in each city either supported or discouraged travel into the CBD, with the share of employment following in predictable ways.

For example, localities such as Minneapolis-Saint Paul, Pittsburgh, and Salt Lake City have a CBD-radial transit route model that does not match "the dispersed pattern of destinations to which transit users wish to travel," Thompson and Brown say. Portland and San Diego, meanwhile, performed better in terms of employment growth in the CBD "because their decentralized transit networks match the dispersed pattern of destinations."

Portland and San Diego also performed best in terms of measures of transit riding habits, service productivity and operating expenses per passenger mile. Both cities link LRT and bus service so that



A two-car Tri-Met light rail train runs through southeast Portland, Oregon, alongside a freeway. Portland's light rail transit system has been very successful, with expanded service bringing a 220 percent ridership increase from 1971 to 1996.

each “could leverage one another to more effectively serve dispersed destinations.” San Diego also coordinated a diverse array of transit operations into a unified system that facilitated transfer and coordination among operators and routes.

Robert Cervero also writes about the relationship between light rail transit and urban development:

Since LRT represents a relatively permanent investment along a fixed guideway corridor, it, like heavy rail rapid transit, has the inherent potential to influence urban growth, affect land uses, promote redevelopment, and increase nearby property values. Importantly, since rail systems improve regional access, new growth tends to cluster around station sites, and declining areas can be rejuvenated because of the

higher value and profit potential of the surrounding land.

The relationship between LRT and economic activity has been explained in other ways. Benefits have been linked to more comprehensive planning paradigms. Cervero notes that “building a light rail system won’t bring about major land use changes or stimulate private investments in and of itself; those goals will require plenty of development incentives and a strong public commitment to concentrated urban growth.”

The motivations of localities for developing light rail and the extent to which planners have a comprehensive planning agenda can influence the development potential of LRT. Short-term cost savings can sometimes come at the expense of long-term land development benefits. Sometimes, LRT routes are aligned along abandoned railroad corridors and industrial belts, where land was relatively inexpensive, rather than in mixed-used or denser neighborhoods where land is relatively expensive. When light rail lines are developed on established physical routes, such as former rail lines, even though passenger travel in the present day no longer follows those patterns, the light-rail system by itself will likely fail to raise property values or drive economic activity in the areas surrounding the stations along the route.

A comparison of LRT-associated development outcomes between one of the least and most successful cases in the United States suggests both the limits and possibilities of LRT as a development agent. Buffalo, New York, and Portland, Oregon, are two cities with stagnating downtowns where planners saw LRT tied to pedestrian transit malls as a way to ignite a revival. By the third quarter of 2012, the ratio of transit trips to the population of metropolitan Buffalo was 2.0 percent, in comparison to 5.8 percent for metropolitan Portland.

In Buffalo, the Department of Community Development became the lead agency in a comprehensive effort to establish a viable downtown core and reverse the exodus of retail stores from the CBD. Buffalo invested in a new downtown civic center and an office/hotel complex, as well as a LRT to service these developments, with the goal of creating 6,700 jobs for the depressed city. After construction of a costly underground system, Buffalo opened its LRT in May 1985. The Buffalo Metro line was faced

with the threat of a shutdown after the first year because of major operating deficits and ridership only a little more than half of what was predicted. Fares paid for less than 20 percent of the Metro's operating costs.

Portland rolled out its LRT in phases after a less costly bus transit system helped promote rights-of-way and ridership. Planners developed a Transit Investment Corporation to leverage private capital through various public improvements and to manage mixed-use joint developments around stations.

As G. B. Arrington describes it, Portland's city center planning model focused "the most intensive development adjacent to transit," with mixed-use development at pedestrian scale. The city placed strict limits on commuter parking and limited the addition to road capacity serving the downtown to discourage cars and encourage transit ridership. Portland also installed "an urban growth boundary . . . that legally defines what's urban and what will remain rural."

From 1971 to 1996, Portland's regional transit agency Tri-Met expanded service by 140 percent and saw an increase in ridership of more than a 220 percent. By 1996, roughly 40 percent of downtown work-related trips included the use of transit. One study published that year reported that improved transit access, together with extra housing and other improvements, helped increase the downtown district's share of the metropolitan area's total retail turnover from 5 percent to 30 percent.

Decline of traditional manufacturing hurt Buffalo but spared Portland, a city tied to more dynamic high-technology sectors. Cervero concluded, "For LRT to have an extensive impact on urban form, a strong and growing regional economy is an important prerequisite." Yet, Thompson also shows that transit planning can be an independent variable, such that even fast-growing cities can choose less successful LRT configurations.

Cervero noted that San Diego's system increased downtown retail sales at the expense of border communities, meaning that LRT can redistribute business activity without necessarily fueling growth. Other planners argue LRT's primary goal is to compete with car trips and serve areas that have established high levels of employment and car use but that LRT can't autonomously trigger a regeneration process.

Sustainability

Cervero summarized various advantages of LRT compared to other modes:

[LRT] is relatively quiet, thus environmentally unobtrusive; is electrically propelled, thus less dependent than buses on the availability of petrochemical fuels; and can operate effectively along available railroad rights-of-way and street medians, thus is far cheaper, less disruptive, and easier to build than heavy rail.

This assessment was before bus rapid transit (BRT) emerged as important in discussions about new forms of mass transit system delivery. Some studies have argued that BRT provides higher performance and significantly lower costs per passenger trip in medium- and low-density cities.

However, Thompson and Brown's later review of different cities and studies found "no meaningful difference in the capital expenses per passenger miles between cities choosing to invest in bus rapid transit facilities and those investing in light rail facilities." The authors note that express buses on high occupancy vehicle lines typically can't provide certain forms of regional connecting service "because they usually lack the stops for accessing regional destinations and for providing transfer opportunities."

LRT systems have been able to provide such linkages. In Sweden, the successful Tvärbanan LRT system in Stockholm uses specially dedicated bridges, tunnels, and rights-of-way to connect commuters from transit lines and commuters using heavy rail lines or buses following a traditional hub-to-spoke (downtown to outlying residential area) pattern.

John M. Stutsman's study of Los Angeles transit systems indicated that LRT was "environmentally superior to BRT (especially in relation to noise and traffic impacts)" and had "more new daily transit riders," but BRT was "somewhat more cost-effective."

Using a different methodology, Richard Stanger's study of Los Angeles regional transit found that the Blue and Gold LRT lines had an average travel speed 40 percent greater than the Orange Line busway's speed, even though the bus has an exclusive right-of-way for 90 percent of its length. The operating cost was \$0.46 per passenger mile for rapid buses, \$0.53 per passenger mile for the Freeway Busway, \$0.48 for the Orange Line, \$0.42 for rapid

transit (the heavy rail metro) and \$0.50 for LRT lines. The subsidy was \$0.46 per passenger mile for rapid buses, \$0.45 for the Freeway Busway, \$0.36 for the Orange Line, \$0.29 for rapid transit and \$0.41 for light rail lines.

A national study by Edson Tennyson found in 1989 that rail transit was “likely to attract from 34 percent to 43 percent more riders than will equivalent bus service.”

Lewis Lesley notes that cost discussions must also figure in the potential role played by development:

The first stage of London Docklands light railway, which opened in 1988, was paid for within three months of the start of construction, through the rise in the value of brownfield sites and land sales.

Yet, he explains, not all regions would be able to capitalize on overheated land values.

Cities such as Pittsburgh in the United States and Manchester in the United Kingdom are viewed as post-industrial cities that have had success in building a growth model supported by LRT. Yet, the greater Portland region also has leveraged its local capacities in LRT as a transit service to also support a relatively new manufacturing effort to build streetcars.

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See Also: Bus Rapid Transit; Busways and Reversible Bus Lanes; Cable Cars; Green Transportation; Rail Transit Planning, U.S.; Rail Transit Planning, Worldwide; Sustainable Transportation; Tramways; Transit-Oriented Development.

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Light-Duty and Pickup Trucks

Light truck is a U.S. legal and industry classification for motor vehicles. Title 40 of the Code of Federal Regulations defines light truck as designed primarily for purposes of transportation of property or [which are] a derivation of such a vehicle, designed primarily for transportation of persons

with a capacity of more than 12 persons, or available with special features enabling off-street or off-highway operation and use, where such vehicles have a gross vehicle weight rating of no more than 8,500 pounds. The legal classification includes pickup trucks, sport utility vehicles (SUVs), and vans, and groups together those trucks that are similar enough to automobiles to not require a separate driver's license classification. Buses, larger trucks, and other commercial vehicles are covered under the requirements of the commercial driver's license.

The "Chicken Tax"

Vehicles are classified not just for licensing purposes, but also for taxation and sometimes surprising policy purposes. For instance, the "chicken tax" is a steep 25 percent tariff on imported light trucks with an interesting history and lasting effect.

The odd-sounding tax takes its name from a ban on American chicken imports by France and Germany in the early 1960s, when a revolution in American poultry farming had made U.S. chicken the cheapest on the world market. As a punitive response, in 1963 President Lyndon Johnson imposed a tariff on imports of some of the major goods France and Germany exported, including brandy, dextrin, potato starch—and light trucks. The tariffs on brandy, dextrin, and potato starch have since been lifted, but the light truck tariff has remained for 50 years, even though there is little rationale to preserve the tariff today.

The release of recordings from the Johnson administration has since revealed that the stated issues with France and Germany were never the real reason for the light truck tariff. Rather, it was developed as part of Johnson's discussions with the United Auto Workers (UAW) union and the possibility of a strike, which would have put Johnson at a disadvantage when seeking reelection.

In return for not striking, the UAW wanted something done about Volkswagen's aggressive attempts to command a larger share of the U.S. market. The resulting chicken tax reduced the price advantage of Volkswagen vans. Because the chicken tax did not specify a country of origin for its tariff, it later made it more difficult for Japanese and other foreign manufacturers to compete in the light truck category with American manufacturers. This is one reason why the pickup truck category has been

dominated by American manufacturers in subsequent decades, even as imported passenger cars have become more common.

Foreign companies have made repeated attempts to find loopholes in the tariff. Japanese manufacturers for a time imported trucks into the United States without truck beds or cargo boxes, which were attached by the retailer before sale. This loophole was closed in 1980. At one time, the Indian manufacturer Mahindra and Mahindra had a plan to export its light trucks to the United States in the form of kits to be assembled by the retailer, although that idea was tabled. Even U.S. automaker Ford has had to make adjustments. It imports trucks from its plants in Turkey that are equipped with rear seats to qualify them as passenger vehicles. The seats are removed after importation and the vehicles are then sold as pickups.

One of the reasons the light truck classification uses transportation of property as a criterion is that many regulations presume that light trucks are used more for practical or work purposes than as personal transportation, while cars are used principally as transportation of passengers. This presumption has, of course, been challenged; many pickup trucks are used both for utilitarian reasons, such as transporting goods that are not possible or practical to transport in a car, as well as for personal transportation. Another angle on the discussion revolves around minivans and SUVs, which are used and marketed as having truck-like utility. Further, manufacturers question whether utilitarian vehicles should be subject to different regulations than those for personal transportation.

CAFE Standards

One area where the classification of a vehicle has broad financial implications for automakers is in compliance with the Corporate Average Fuel Economy (CAFE) standards, introduced in 1975 when volatile oil prices and the maturation of the environmental movement coincided to bring about a new level of concern over fuel efficiency. CAFE standards are not based on individual models, as emissions and safety standards are, but on the average fuel economy of a manufacturer's entire current-model-year fleet.

For CAFE, the fuel economy of all of the vehicles in a given class sold by the manufacturer in that model year is averaged out. If that average fuel

economy does not fall within the specified standard for the vehicle class, the manufacturer pays a penalty based on the number of 10ths of a mile-per-gallon that the manufacturer's total production for the domestic market varies from the standard. Since 2011, the fuel economy standard to which manufacturers' averages are compared has been derived from a mathematical formula that depends principally on the vehicle's footprint.

The larger the footprint of the vehicle, the lower the fuel-efficiency standard to which it is held—and the easier it is for manufacturers of larger vehicles to avoid costly penalties. Light trucks are also exempt from the Gas Guzzler Tax, which is assessed on passenger cars with a tested fuel economy of less than 22.5 miles per gallon.

Safety

Traffic fatalities are the leading cause of death for Americans under 40, and conventional wisdom has long held that heavier vehicles are safer for their occupants. The National Highway Traffic Safety Administration (NHTSA), which regulates CAFE standards, has advocated this belief and expressed concern over federal efforts to encourage greater fuel economy. In the NHTSA's view, lighter vehicles are more fuel-efficient, but they are also more dangerous vehicles. Although this perception is not the source of the separate fuel-efficiency standard for light trucks, it has, in effect, encouraged light truck ownership and deterred the development of more fuel-efficient light truck designs.

However, studies conducted in the wake of tremendous growth of American truck ownership have suggested that light trucks do not necessarily adhere to the heavier-is-safer rule. Their maneuverability and braking are markedly worse than comparable automobiles, and their higher center of gravity makes rollovers more common.

Further, the benefits of their greater size and weight apply only to the light truck's own passengers, making accidents involving these vehicles more dangerous for the occupants of most passenger cars. Now that light trucks represent half the number of the vehicles on the road, this has become a significant factor in overall road safety.

Automobiles are designed to prevent the passenger cabin from being penetrated in a collision, but the safety features protecting the cabin assume a collision with another automobile. Trucks,

however, ride high enough to bypass the safety bumper that is designed to keep colliding vehicles from penetrating the cabin. Further, heavier trucks may have a sturdier construction, but that also means they exert more force than a lighter vehicle during a collision. All other factors being equal, then, truck-car accident can have results much more damaging and severe than a car-car accident. A study by the National Institutes of Health found that the net effect on road safety is negative—more trucks mean more fatalities—and the fatalities are disproportionately distributed, with about 80 percent of them affecting occupants of the nontruck vehicles.

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See Also: Automobile Design; Driver Licensing, Commercial; Passenger Van Safety; Sport Utility Vehicles; Trucks, Safety Issues and; Vans.

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Liquefied and Compressed Natural Gas

Liquefied natural gas (LNG) is natural gas that has been liquefied for storage, whereas compressed natural gas (CNG) remains in gaseous form, although it is compressed to a fraction of its natural volume so it can be stored and transported in cylinders exerting pressure of 3,000 to 3,600 pounds per square inch.

Natural gas is a hydrocarbon gas that occurs naturally deep underground, especially in proximity to other hydrocarbon deposits, such as crude oil and coal. Consisting mainly of methane, natural gas includes nitrogen, hydrogen sulfide, carbon

dioxide, and a number of other chemicals, and is generally called natural gas in order to differentiate it from other gases and from gasoline. Natural gas is commonly used in the United States as a heating and cooking fuel, and it can also be used as an alternative vehicle fuel to gasoline or diesel. Natural gas is simply called gas in English-speaking countries outside the United States, where gasoline is called petrol.

Natural gas is a frequent by-product of oil drilling. It used to be burned off at the oil field in order to dispose of it, because of the difficulty of transporting it to a market at an efficient cost. Today, pipelines exist to transport even nonliquefied natural gas to markets, because natural gas has become so valuable as a fuel.

Biogas is natural gas produced through the anaerobic decay of nonfossil matter rather than through the thermogenic processes that create natural gas deep underground. Biogas is naturally formed within swamps and marshes, as well as produced within landfills, where its presence can be a hazard if it is not harvested, and masses of sewage, where it is a byproduct of decay processes.

Natural gas is fairly well exploited in the United States, except where conditions make harvesting too difficult to be cost efficient. Biogas, however, often goes unharvested. Most landfill gas is just burned off in controlled fires in order to reduce the possibility of uncontrolled explosions. Biogas produced as a byproduct of sewage treatment is an exception, and such gas is often used in electricity generation.

Hydraulic “Fracking” Controversy

Natural gas contained in formations of shale, a sedimentary rock of mineral flakes and particles embedded in mud, is called shale gas, and it has become the fastest growing source of natural gas. Historically, shale gas has proven difficult to extract, with the cost of extraction exceeding the value of the gas. Commercial shale gas production didn't begin until the 1970s, when the decline of other natural gas reserves and the energy crisis of that decade made it appealing.

Tax credits and government grants for shale gas extraction research fed the industry for some time, but shale gas exploration really took off in the 21st century, climbing from 1 percent of U.S. natural gas production at the dawn of the century to 20 percent by 2010. It is expected to account for half of natural

gas production by mid century. Shale gas production is accomplished through hydraulic fracturing, or “fracking,” which uses a pressurized liquid to fracture the rock layers in which the shale gas is contained to release the gas for extraction.

The vast majority of fracking is done in the United States, but the environmental and health consequences have invited controversy. Critics contend that fracking compromises the quality of underground water supplies, consumes vast amounts of water at a time when droughts are a recurring problem in parts of the country, releases greenhouse gases into the air, and requires more energy in the extraction than the gas itself yields once extracted. Significant concerns have also arisen around small earthquakes induced by fracking, as well as the radionuclides associated with and released by the process that may introduce radium to the water supply, and the disposal of toxic fracture fluid after use.

In many circles, the production of shale gas by fracking is believed to have a greater negative environmental effect than the energy benefit of gas production. The health consequences are seen as significant, especially given the proximity of many fracking or potential fracking sites to human settlements. Air and water pollution are allegedly becoming much more severe, and carcinogens and toxins that can lead to chronic illness are being introduced, critics say.

In response to the concerns raised by fracking in the United States, other countries have begun banning the process, and it remains unclear how stricter regulation, if it occurs here, will impact the economic feasibility of shale gas production. The capital investment in shale gas production equipment—as well as in other natural gas exploration, production, and processing technologies—depends on the natural gas extraction being profitable in order to be worthwhile. Although many experts believe that the natural gas reserves in the United States would take a century or more to deplete, recent research has suggested the possibility of a deliverability crisis in the near future as resources become increasingly expensive to access.

Processing Natural Gas

Whatever the source of natural gas, like other naturally occurring hydrocarbons, it is processed before it is usable as a fuel. Processing removes water vapor, impurities including radioactive gases and mercury,



A member of the U.S. Navy fills a government vehicle with compressed natural gas (CNG) from a naval base fuel supply in Jacksonville, Florida, August 2005. Lack of access to many CNG refueling facilities may limit private use of CNG vehicles.

and heavier hydrocarbons such as propane and butane, which have their own industrial uses. The end product is a gas that is primarily methane with a mixture of nitrogen and carbon dioxide.

Liquefied natural gas is often confused with compressed natural gas, the form of natural gas used as a vehicle fuel. However, LNG refers only to a specifically prepared form of natural gas that remains in liquid form only for the purposes of transport and storage.

LNG is produced primarily overseas, where production occurs in order to transport the natural gas to a place where it can be sold. The gas is liquefied by cooling it to minus 163 degrees C (minus 261 degrees F). LNG is produced mainly in Qatar, Russia, Indonesia, Algeria, Brunei, Egypt, Malaysia, Nigeria, Australia, and the United Arab Emirates. From there, it is transported to LNG-receiving terminals in 18 countries. It is transported by specially designed LNG tanker ships, which are equipped with four to six tanks surrounded by ballast tanks and voids.

CNG is a natural gas that has been compressed for use as a fuel, but not to the same degree as LNG, which has been compressed for transport. CNG can be used in internal combustion engines and is often used in bi-fuel engines, which are capable of running on two fuels, one being diesel or gasoline

and the other being an alternate fuel such as CNG, liquefied petroleum gas or hydrogen. In much of the world, CNG is beginning to be used in larger vehicles such as buses and trucks. It can also be used in locomotives. Because these larger and heavier vehicles consume more fuel, the cost of conversion to bi-fuel is more quickly returned than in a smaller automobile. However, Volkswagen, Toyota, Honda, Peugeot, and Fiat all manufacture bi-fuel cars for some markets.

CNG is a cleaner fuel than gasoline, although it does emit some greenhouse gases. Because it is leadless and free of benzene, it does not create lead buildup on sparkplugs as gasoline does, nor does it contaminate crankcase oil. CNG has a narrow range of flammability, which makes explosions in accidents less common. Its pollutant levels of carbon dioxide, carbon monoxide, unburned hydrocarbons, nitrogen oxides, sulfur oxides, and particulates are lower than for gasoline. However, whether CNG usage results in lower in greenhouse gas emissions over the life cycle of the fuel being used depends on how the CNG is produced. When dirtier methods of fuel production are required to offer a fuel that is cleaner to use during the consumer's usage, environmental gains may be small, if any. That said, there are economic as well as environmental motives for natural gas use, and not every method of natural gas production has the same level of environmental impact as fracking.

The drawback to CNG as an automobile fuel is that natural gas takes up more space than the equivalent amount of gasoline or diesel. Larger vehicles can accommodate this without much difficulty. Some CNG-burning buses use rooftop tanks, for instance. Factory-built bi-fuel cars typically use tanks on the underside of the vehicle, which is common in Volkswagen's bi-fuel vehicles, for instance.

Drivers who convert their existing cars to CNG must find another solution, usually installing a CNG tank in the trunk of a car or the bed of a truck to reduce the storage space. For this reason, CNG usage is not as appropriate an alternative for as many vehicles as biodiesel and gasoline-ethanol mixes. Also, as with other alternatives to gasoline use, the use of the vehicle is dependent on an available source of fuel. While transit companies can maintain their own tanks of CNG, this tends to be impractical for most private individuals.

The greatest concentration of CNG-using vehicles is found in countries where natural gas is produced, including Iran, Pakistan, India, Brazil, and Argentina. CNG taxis are common throughout South America, and Argentina and Brazil have the world's largest fleets of CNG vehicles for this reason, with significant numbers in Colombia and Peru, as well. Singapore, which pioneered the use of CNG in public transit and delivery vehicles, has seen a rise in the use of CNG in private automobiles driven by rising gasoline prices and growing awareness of CNG as an alternative. The government of Singapore offered a rebate to new owners of green passenger vehicles, including CNG cars, from 2001 to 2012, contributing to the growth of the sector.

The United States has actively encouraged natural gas as a vehicle fuel, but the number of natural-gas-using vehicles barely increased from 2000 to 2010. Thirty-four states have at least one CNG fuel station, and CNG often costs about half the price of gasoline, but it remains a niche market. Transit companies and government bodies in California, Massachusetts, and Pennsylvania have converted portions of their fleets to CNG.

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See Also: Air Pollution, Automobiles; Air Pollution/Air Quality; Alternative Automotive Fuels; Alternative Fuels; Bus Engines; Climate Change, Transportation Adaption to; Environmental Impacts; Green Fuels; Greenhouse Gases; Harbor and Port Security; Low-Emission Vehicles.

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Livable Streets

Livable streets are particular forms of transportation infrastructure that account for transportation, land use, housing, and environmental challenges in an integrated and balanced manner to improve the quality of life for a community. In this regard, livable streets can enable context-specific mobility solutions to promote the economy, social well-being, and the environment for different communities in a metropolitan area.

Livable streets can improve the economic livability of a community by providing the means for reliable, affordable and safe transportation that supports the connection of affordable housing with jobs that provide livable wages. Moreover, livable streets can advance a community by supporting transportation designed to sustain public health, personal security, traffic safety and social interactions. In addition, livable streets can improve the environmental livability of a community by positively affecting neighborhood cleanliness, traffic noise and air quality.

Decisions and policies that foster the design and implementation of livable streets are ones that incorporate important aspects of human thriving. Determining what makes streets livable is a difficult task because it involves a degree of subjectivity. Therefore, community leaders, planners, and policy makers need metrics to identify and quantify the elemental attributes of livable streets.

Livable Transportation Systems

In an urban area, livable transportation would make it feasible and safe for people to walk or bike to important amenities, take public transit to work or recreational destinations, and to be able to afford and park a car. In a suburban setting, car ownership is often essential, and livable transportation would allow people to drive safely within a reasonable amount of time to important destinations, to possibly take a commuter train to work, and to walk or bike safely.

Livable transportation systems have the potential to facilitate the achievement of numerous community goals by providing better access to jobs, community services, affordable housing, and schools. To this end, communities need transportation facilities and services of the right quality, location, and type. Communities, businesses, and consumers all benefit from livable transportation systems.

A transportation network designed to make streets livable will take a wide variety of modes into account while encouraging patterns of development that are sustainable. Livable transportation systems can also improve community safety and appearance, and reduce environmental impact, by decreasing energy use and using land more efficiently.

Livable Versus Sustainable Transportation

Because it deals with the quality of life for a specific community in the present and near future, livable transportation is more place-based and near-term-focused. It addresses human concerns such as choice in transportation and housing, as well as access to employment and education facilities. Sustainable transportation is concerned about meeting today's needs without preventing tomorrow's citizens from meeting their needs.

There are distinctions between livable and sustainable transportation systems, although both encourage travel options that are more environmentally sustainable and promote economic development. They also both affect human health, although livable transportation is more about active living and sustainable transportation is more about air pollution impacts. Livable and sustainable transportation systems have policy impacts related to social equity for low-income, young, old, disabled, and minority groups.

Yet, livability and sustainability in transportation systems can sometimes be at odds with one other. In 2009, the U.S. Department of Transportation conducted an Omnibus Household Survey on Public Perceptions on Transportation Characteristics of Livable Communities. While survey respondents said they considered multi-modal and non-privately operated-vehicle (POV) transit, such as sidewalks, bike lanes, and local transit, to be important, they still considered POV facilities, such as major roads and adequate parking downtown, as more important.

Livable transportation is enhanced, consumers were saying, by owning a car and being able to use it freely. From the viewpoint of sustainable transportation, however, these consumer sentiments would be outweighed by the environmental impact of driving a car, which leads to increased gasoline consumption, greenhouse gas emission, and climate change. The challenge for planners is to balance these conflicting forces in ways that enhance

quality of life in the community without degrading the environment.

Transportation Planning Process

One of the goals in urban planning is to make communities more livable. This encompasses numerous elements, including transportation, its systems, and its infrastructure. During the planning period, transportation practitioners engage other stakeholders to form forward-thinking ideas, address broad issues, develop understanding of potential outcomes and choices, and develop integrated solutions for the long term. New planning and process methods help incorporate livability goals, integrate mobility with other community needs, reach more participants, develop creative plans, and help align fiscal realities to actual transportation costs, thereby improving project delivery.

Updated policies can help integrate livability goals across the spectrum of a transportation agency's projects, but bringing about such changes requires political backing, buy-in from staff and leadership, and strong external partnerships. Such partnerships can involve public, private, and nonprofit agencies, all of which can help meet funding, policy, program, or planning goals. Designing for livability necessitates knowing those who plan to use the system by integrating their input throughout the design process. Coordinating transportation investments and livability goals can improve performance of the system and leverage more funding.

Land Use as a Supply-Side Factor

The supply-side factors that affect transportation and livability include land use, urban design, and roadways. Land use is an important factor because land-development patterns influence transportation patterns, and transportation patterns influence land-development patterns. More specifically, land-development patterns influence where a person lives, works, goes shopping, socializes, and exercises. Transportation patterns influence how people get to and from these places, the travel mode they use, the length of time it takes, and the expense incurred. These factors are significant in determining the livability of a place, as well as its transportation infrastructure, including its streets.

Transportation and livability vary from place to place, and from land use to land use. In a dense urban setting with a mix of commercial spaces and

residences, a livable transportation system would be different from that in a less dense suburban setting where land uses are more separated. That setting, or context, has an influence on how people travel. Overall, a community with many destinations in close proximity also provides people with more options about which transportation mode to use. In such a setting, livable transportation may look like biking to the store, walking to the bus stop to go to work, and driving to a theater to see a play.

In a community with fewer destinations accessible nearby, people have fewer options about transportation mode choice. In this type of setting, livable transportation may look like being able to drive to the store easily and park without a hassle, to drive to work without too much congestion, to possibly take commuter rail to work because there is a station nearby, and to walk or bike to the local park to enjoy a weekend afternoon. Land use does not dictate what transportation options a person has, but it does significantly influence them.

Urban Design as a Supply-Side Factor

How the space is designed determines how land is used. Urban design deals with how buildings are arranged, parks are located, and streets are laid out. Urban design influences transportation because it deals with street design, from how wide streets are and the pattern they take to how they connect to other streets and how well-suited they are for walkers, shoppers, and bicyclists. These are all factors that affect the transportation network and the livability of the community that transportation network serves.

Urban design also deals with the streetscape, how the street looks, is structured, and what features are present. This can include the width of the sidewalk, planting of street trees, location of signs, width of traffic lanes, inclusion of bicycle lanes, presence of a median, and placement of parking. These factors, and others, make up the streetscape and can have a significant impact on the livability of a community. Streetscape considerations help determine whether streets and sidewalks are safe for all users, how attractive an area is, whether people want to be out on the street to interact with neighbors, and how local businesses are situated and accessed.

The effect of urban design on livability depends significantly on the context. A gridded street network in a dense urban neighborhood is likely to

promote transportation choices and be more livable. A cul-de-sac-type layout in a low-density suburb is likely to meet the preferences of the residents there, even though it could impede travel in some ways. The streetscape of a community significantly influences the travel that occurs there and the social and economic vibrancy of a place, too. As transportation-related livability factors vary from place to place, so, too, do the urban design factors necessary to make a place livable.

Roads and Highways as a Supply-Side Factor

A dense road and highway network means that destination accessibility by road is very high. A person can use a road to travel almost anywhere. Roads enhance mobility, the ability to travel to destinations quickly. Accessibility, which is the ability to get to destinations, and mobility, which is the ability to get to destinations quickly, both significantly improve livability.

Planning, design, and construction improvements can help improve roadway capacity issues, providing congestion relief, especially during peak hours. Road congestion harms livability because it delays, and often frustrates, drivers. Traffic congestion also increases emissions and fuel use.

One possible solution to congestion would be new road construction, but in many cases, especially in urban areas, there may be no room to build new roads or add lanes to existing highways. In these cases, transportation agencies use strategies such as travel demand management, which encompasses a variety of efforts including carpooling, telecommuting, congestion pricing, biking, walking, and shifting mode share from car to transit.

Agencies can also improve system efficiency through management and operations strategies, which can include access management, intelligent transportation systems, incident management, and freight and goods management. The roadway network is an essential part of the transportation system, and it needs to be well managed to operate efficiently and to provide livable conditions for all who use it.

Roadways are not only conduits for cars to get from one place to another; they are also a major part of the physical environment of communities and a significant factor in how people feel about their communities. The same person living in the same house will likely feel very different if the house is

next to an expressway as opposed to being next to a gravel road.

Studies have shown that streets affect feelings of safety, social interactions, and physical awareness of one's surroundings. Busy streets are less livable for the people living alongside them. Livable streets, on the other hand, act more like an extension of the residences nearby. Cars can travel along livable streets, but physical features can be designed to cause cars to slow down, making the streets more livable for residents. Such streets can have multiple benefits for residents with respect to safety, health, community, and property values.

The environmental impacts of paved roads can also be significant. The impermeable surface that pavement creates prevents water from naturally soaking into the ground when it rains. Normally, this runoff is handled by a city's storm water system, but paved surfaces can increase the likelihood of flooding. Pavement also can be a factor in creating an urban heat island, where the pavement absorbs heat during the day and releases it at night; this can be particularly problematic during summer months when heat turns ozone into smog.

Efforts are underway to address environmental problems associated with roads. The sustainable streets movement seeks to reduce the environmental impact of paved streets, among other goals. To manage storm water runoff more effectively, some streets are now made with permeable paving material that allows some water to seep through to the soil below. Sustainable streets also might incorporate landscaping features that allow some storm water to run off into planter boxes along the roadway. This helps manage the volume of water flowing through the storm water drain system.

Sustainable streets are able to mitigate the urban heat island effect through the planting of trees and other vegetation along the road or down a median in the road. By shading the roadway and preventing it from absorbing as much heat, plants have a natural cooling effect. Roads can also be constructed with lighter colored materials, such as concrete rather than asphalt, to help reflect the sun's rays rather than absorb them.

Sustainable streets, therefore, improve livability by reducing flooding and its associated damage, decreasing heat to reduce air conditioning costs and smog-related health problems, and improving aesthetics through the presence of trees and plants.

Although roadways are primarily built for automobiles, they can contribute to the livability of communities when the transportation needs of all users are considered during the design and planning. This means making streets safe, practical, and attractive not just for cars but also for walkers, bikers, and transit riders. This method of "complete streets" planning can have many benefits.

When a family can get to some of their important destinations without having to use a car, it could become possible for them to reduce their car ownership, which is typically a significant portion of a family's expenses. Complete streets make it safer and easier for both the young and old people to get around, freeing them from depending on someone else for a ride. Complete streets can benefit drivers, too, by making roads safer and reducing the number of cars on the road as more people walk, bike, or take public transit.

These well-managed, livable, sustainable, complete streets cannot be built all at once, however. In the meantime, transportation agencies can enhance their roadways by selectively choosing where to target their investments. A traffic bottleneck, for instance, could be eased by adding an additional lane, if possible, or implementing a congestion pricing system to shift the demand. Streets do not need to be ripped up just to put in permeable pavement; it could be done when a street is already scheduled for reconstruction. Some aspects of the livable streets concept could be tried on a limited number of streets to see how people respond. If those measures prove successful, livable streets could be implemented on a wider scale. Each of the actions along the way had the possibility of enhancing livability, and, collectively, they could make a significant impact.

Demand Side Factors

In addition to the three main supply-side factors—land use, urban design, and roadways—demand-side factors also affect livability and transportation. Demand-side factors can also be characterized as modal factors or choice in transportation mode. For people, livability improves when they have convenient access to a mode of transportation that fits their needs and is safe and affordable. Choices about the mode to use can be made at an individual level, but decisions must be made at the community or regional level to make

the modal transportation choices available and safe in the first place.

Cars as a demand-side factor. Since roads are so ubiquitous and cars have the ability to access destinations served by roads, cars have a high degree of accessibility. Drivers can go just about anywhere they want to, even though their usual travel is within a relatively short distance from where they live. Drivers can generally travel to their destination at a faster rate by car than by any other mode. The speed of cars makes them highly mobile. This combination of mobility and accessibility means driving is generally convenient and saves a traveler time. All of these attributes enhance livability.

It is advantageous to own a car for the sake of employment, too. In general, when controlling for socioeconomic and demographic characteristics, car owners make more money and have more work hours per week than those who don't own cars. Similarly, participants in the welfare-to-work program are more likely to be employed if they own cars. Employment is a significant aspect of livability, so it would seem that car ownership could be connected with livability for this reason.

From a livability perspective, cars are a positive factor, but, of course, there are downsides. The cost of owning, insuring, licensing, registering, maintaining, parking, and fueling a car can be burdensome. Driving can be stressful, and longer commutes have been shown to lower the commuter's subjective well-being. While car crashes can have a negative effect on a victim's health, and sometimes lead to fatalities, cars are also hazardous when they are being driven safely. They contribute to air pollution and global warming by producing exhaust gases that include ozone, particulate matter, nitrogen oxides, carbon monoxide, and carbon dioxide.

Transit as a demand-side factor. The benefits of using public transit can be significant for both users and nonusers, and those benefits contribute to the livability of the communities where it is available. Transit provides mobility for people who cannot drive or are unable to afford a car, while lessening road congestion for drivers by providing alternative transportation for potential car users. Public transit allows riders to be more efficient, giving them the opportunity to catch up on reading, writing, checking email or social media on a smartphone,



This street in the High Point neighborhood of West Seattle, Washington, incorporates wide landscaped swales that catch stormwater runoff from the paved road surface.

or simply relaxing. Moreover, transit out-of-pocket costs are significantly lower than owning and driving a car.

Beyond individual communities, public transit can improve livability for a large metropolitan area or a whole region by providing an affordable network of transportation options, reducing pollution, cutting down road congestion, and fostering the development of both residential and commercial construction around stations.

The downsides of public transit include the inability of fixed-route systems to access as many places as private automobiles, crowds during peak hours, and comparatively slower travel times in comparison to private cars, although that is not always the case. Express trains and buses, for example, can easily move people more quickly to suburban destinations during rush hours than cars.

Bicycling and walking as demand-side factors. When bicycling and walking are safe, viable, and attractive options, they can be excellent modes of transportation and enhance livability for individuals and communities. The cost of biking and walking are negligible, in most cases, and these forms of "active transportation" have been positively correlated with improved health and negatively

correlated with obesity and diabetes. Not only does active transportation improve the health of the people who are bicycling and walking, it improves the health of the whole community by reducing the pollution that otherwise would have been emitted.

Infrastructure costs and space requirements are lower for bicycling and walking facilities on a per-user basis than for automobiles. Moreover, real estate values may rise for housing near biking and walking trails. Active transportation can also help those who are driving cars by reducing road congestion.

On the other hand, walking and bicycling are more limited in scope than driving and public transit, meaning it is harder to travel as far. Safety concerns, both real and perceived, exist for walkers and cyclists, especially where these people are likely to interact with cars and other vehicles. It is also harder to walk or bicycle in very hilly terrain or when the weather is extreme. These limitations illustrate the necessity to plan and provide facilities for walking and bicycling and also to recognize where these modes fit in the larger transportation system.

Freight as a demand-side factor. While not a mode of travel for passengers, the way freight is transported affects livability. A freight transportation system that operates efficiently is becoming an increasingly important aspect of a successful economic system, and, thus, a livable society. When freight networks, whether rail- or road-based, become congested, substantial delays in freight shipments can harm the economic viability of an area or, in the case of a national network, the entire country.

Other challenges with freight exist. Freight movement, especially in a central business district, can pose challenges for truck drivers, automobile drivers, merchants, and pedestrians. These challenges can relate to safety, pollution, congestion, and logistics. Because it is necessary to deliver goods, freight movement is a consideration for planners when it comes to livability.

Impact Evaluation Issues

The main objective of livable streets initiatives is to improve the quality of life for individuals and the community, while balancing out economic and environmental concerns. The fact that livable streets affect so many aspects of human activity introduces substantial complexity in the measurement of their impact.

Research in the areas of psychology, economics, urban design/architecture, urban planning, sociology, regional science, and transportation reveal that there are significant variations in the interpretation of the terms *quality of life* and *livability*. For example, in the field of urban planning, someone with an urban design background would tend to view livability from an aesthetic perspective, but another person with an economic development focus would tend to see economy vitality as a more significant determinant of livability.

In constructing appropriate indicators to measure livability, a number of issues need to be addressed. While quality of life is measured at the individual level, livability is typically associated with communities. To further complicate the matter, aggregating or averaging individual quality-of-life measures does not necessarily result in an indicator that reflects collective experiences.

In the struggle to reconcile subjective quality-of-life measures for individuals with indicators of the livability of an entire community, the following major issues would need to be addressed in evaluation efforts.

Weighting indicators. While there is no perfect framework to connect quality of life, which is inherently a subjective and personal concept, with the livability of a community, it is clear that measuring livability must take into account heterogeneity in people's preferences and priorities. For example, accessibility to primary education facilities or employment opportunities would have little effect on the livability of a retirement community. One approach to this problem is to give various factors different weights that would account for different preferences of the demographic and socioeconomic groups in the community.

Appropriate scale for analysis. Transit indicators of neighborhood livability, for example, cannot always be scaled up to a regional or state level. Similarly, large-scale indicators are not necessarily relevant at the community level. Even if scaling up or down is possible, it may not make sense from a policy perspective. Within the scope of a transportation demand management (TDM) strategy, for example, "walkability" would be measured only at a local scale and would be relevant only up to a regional scale.

Statistical measurement. What statistical measures would best capture a particular livability dimension? For example, indicators that measure public transportation quality, such as “mean waiting time for service,” are commonly employed. However, from a livability perspective, what is important is not only (or even mostly) the average waiting time but also the distribution of waiting times. If the average waiting time is five minutes but the range of waiting times extends up to 30 minutes or more, the service quality from the community perspective is very different from an individual’s.

Single-sphere versus crosscutting measures. Simply providing indicators related to the economic, social, and environmental aspects of a place would preserve a fragmented view of livability. However, linking indicators through the creation of crosscutting measures might not clearly reveal the preferred direction of indicator change because processes in multiple spheres operate on different scales. For example, measuring bus vehicle miles divided by the number of peak vehicles would create an indicator of how intensively the equipment is used, and it would be influenced by bus travel speeds and different levels of service during peak and off-peak time periods. The direction of the indicator is known since a more uniform demand for service over the day would result in a higher number.

This indicator, however, tells nothing about the impact of the service on the community. Another indicator that might be used would measure the volume of pollutants removed (because of reduced auto driving) divided by bus vehicle miles. This would be more informative from a livability standpoint, because it relates to a quality-of-life outcome, but it would be difficult to make assumptions based on the measurement’s direction because pollutants from mobile source emissions are impacted by a host of interrelated factors.

Indicator interpretation. Livability indicators developed in one place and time might not be relevant in another place and time.

Data availability and reliability. Increasingly, due to scarcity in readily available and suitable public data, proprietary data on livability have emerged. These proprietary data, although useful, are costly, with questionable reliability and availability over time.

Politics of use. Because of the politically contentious nature of policy and planning, indicators can trigger livability exercises that could become excuses for taking no action.

Measuring Transit Availability and Accessibility

Availability is a measure of the supply of transit as provided by the agency. While there are different indicators for measuring availability, commonly used indicators include the frequency of service, hours of service, and the service coverage. These measures are aggregated into an index for transit availability, which is calculated as the percent of person-minutes served.

Accessibility is a key component of livability that explicitly or implicitly underlies many measures and analyses of livability. Accessibility is also closely intertwined with policies that intentionally or unintentionally influence livability. Many livability measures assume that the resources and opportunities at a place are perfectly available to individuals who are proximal to that location. Policies that attempt to influence livability also make this assumption. However, factors other than proximity can affect the ability of individuals to obtain resources and opportunities. This means that measures can overestimate livability, and the effectiveness of related policies, by masking individual variations in the benefits actually obtained from resources and opportunities.

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See Also: Bikeways/Bike Lanes, Road Design Issues of; Commuter Paradox; Complete Streets; Pedestrian-Friendly Design; Street Design/Patterns; Sustainable Transportation; Transit-Oriented Development; Urban Sprawl Versus Compact Development; Urban Trail Systems; Visual Pollution; Walking.

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Low-Emission Vehicles

Low-emission vehicles (LEVs) are a subset of the global motorized road transport fleet that produces comparatively fewer emissions than those produced by a conventional internal combustion engine (ICE) fueled by gasoline or diesel.

The reduction in emissions is achieved through the implementation of a range of technological improvements that increase the efficiency of the vehicle or through the utilization of alternative fuels, such as biofuels, gas—most commonly compressed natural gas (CNG) or liquefied natural gas (LNG)—electricity, and hydrogen. Any of these alternatives may also be used in combination with

conventional fuels. One example is the current hybrid-motor systems used in passenger automobiles, which use both battery technology and fossil-fuel-powered internal combustion. While the term *vehicle* could be wide-ranging, most of the policy focused in this area, as well as the technological developments made, have been in the passenger car and light-duty truck sectors.

Early measures to control vehicle emissions, such as the catalytic converter that became standardized in the mid-1970s in the United States, around the time of the introduction of the Corporate Average Fuel Economy (CAFE) regulations. They were subsequently introduced worldwide and have given way to more systemic vehicle improvements designed to reduce both emissions of air pollutants such as carbon monoxide, nitrogen oxides (NO_x), volatile organic compounds and atmospheric particulate matter. More recently, LEVs have been introduced to reduce the impact of greenhouse gas emissions, primarily carbon dioxide (CO₂).

The issues of pollution addressed by air quality standard legislation and climate change have some complementary solutions, but there are some measures, such as the promotion of diesel engines as a comparatively lower carbon fuel, that actually exacerbate air pollution and the associated health impacts because of the increased levels of NO_x emitted by diesel-fuel engines. Such trade-offs emphasize the need to move toward non-fossil-fuel-based technology but also expose the complexity inherent in such shifts.

The term *LEV* gained prominence after California introduced a LEV program in 1990 that mandated tailpipe emissions standards more stringent than those required by the federal government.

Several variations in terminology have emerged over the past 20 years to differentiate between particular vehicle types. As well as LEVs and zero-emission vehicles (ZEVs), terms that have entered the parlance of the auto manufacturing community include *transitional low-emission vehicles* (TLEV), *super-low-emission vehicle* (SLEV), *partial zero-emission vehicles* (PZEV), *ultra-low-emission vehicles* (ULEV), *super-ultra-low emission vehicles* (SULEV), and *advance-technology partial-zero-emission vehicles* (AT-PZEV). Most of the acronyms developed as California's legal response has progressed, although the utility of such an array of distinctions has been questioned.

Government and Industry Initiatives

Over the past two decades, government and industry initiatives have been developed across the world to promote the introduction of LEVs, with the United Kingdom government even establishing an Office of Low Emission Vehicles to manage the Department of Transport's work in this area.

Following the introduction of the CAFE standards in the United States in the mid-1970s, so-called voluntary agreements to increase the fuel efficiency of new vehicles were struck among members of major auto-manufacturing associations worldwide, including the European Automobile Manufacturers' Association, the Japan Automobile Manufacturers Association, and the Korea Automobile Manufacturers Association in the mid-1990s. The voluntary agreements were largely unsuccessful in delivering the scale of reduction of tailpipe emissions that were targeted by the companies, and in Europe, at least, manufacturers are now mandated to deliver reductions through the 2009 CO₂ regulations for cars.

Despite the failure to achieve the specific targets, numerous significant technological advances were made over the time of the agreements to improve the efficiency of conventionally fueled vehicles in the area of emissions. Such measures include light-weighting through manufacturing cars using lighter and more resilient materials; regenerative braking, where energy ordinarily lost in speed reduction can be stored and used to power the vehicle and save fuel; and through the use of low-rolling-resistance tires.

There have also been developments across the world to shift fleets away from oil toward less emission-intensive fuels. In the 1990s and early 2000s, much attention was given to the potential of bio-fuels (ethanol) and CNG as potential gasoline substitutes because they were relatively low-cost, and, in the case of biofuel, would require little modification to the current vehicle technologies. Research and pilot programs were initiated, but, for the most part, biofuels have not been widely adopted.

Obstacles to wide biofuel use in passenger vehicles include improvements in the efficiency of gasoline and diesel fuels, and increasing concern over the viability of large-scale biofuel production. The U.S. government's interest in biofuel, for example, fueled a major increase in farmers' growing corn, which then sparked fears that biofuel crops would have to compete with those for food production.



An engineer in a thermal cell research facility at the U.S. Department of Energy's Argonne National Laboratory attaches hoses to an automobile to measure tailpipe emissions in 2009.

Since the introduction of an ethanol fuel program some 40 years ago in Brazil, vehicles powered by ethanol from sugar cane have become so prevalent that the country no longer has any vehicles running on pure gasoline. The fleet runs on either pure ethanol or so-called flex-fuel, a gasoline/ethanol blend (primarily E20-25). Although CNG was seen to hold potential as an alternative fuel in the 1990s, the improvements to conventional-fueled vehicles were sufficient to close most of the gap between gasoline and diesel and CNG. However, CNG and LPG have carved out some niches, such as taxis and transit buses, because the cost of natural gas is much lower than the oil-based fuels.

Since the introduction of the Toyota Prius onto the global market in 2000 (following a successful introduction in Japan in 1997), hybrid electric vehicles that combine a battery engine with a conventional ICE powertrain have shifted the attention of car buyers and automakers toward electrification over the past five years. E-mobility is now being promoted by governments and car companies alike.

In California, regulators have mandated that automakers step up the percentage of ZEV vehicles

sold in California through 2017, when a minimum of 14 percent of passenger cars and light- and medium-duty vehicles must produce zero emissions. In Europe, significant research and development is now focused on delivering electric vehicles and the associated infrastructure for recharging them, although to date sales of the electric vehicles currently on the market have been limited. Obstacles to adoption include the fact that current electricity-generation technology is not low emission.

Conclusion

The concept of the LEV has been accepted over the last 20 years, and the market has been transformed with much more energy-efficient vehicles. However, cars on the whole in the United States are getting bigger, and light trucks are becoming the vehicle of choice for many households. Add to that the trend for people to drive more and further every year and the positive developments being produced by the auto manufacturers in fuel efficiency are being cancelled out. Therefore, the challenge in delivering cleaner air and addressing climate change continues to be immense at the same time that the landscape for policy promoting LEVs seems to be getting more, not less, complicated.

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See Also: Air Pollution, Automobiles; Alternative Fuels; Biodiesel; Biofuels; Ethanol; Green Fuels; Greenhouse Gases; Hybrid Automobiles/Hybrid Electric Vehicles; Neighborhood Electric Vehicles; Sustainable Transportation; Zero-Emissions Vehicles.

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Maglev Systems

Maglev, an abbreviation for magnetic levitation, describes the old idea but relatively new technology of using magnets to move noncontacting vehicles at high speeds reaching 250 to 300 miles per hour or more while they are suspended, guided, and propelled above a guideway. Despite the fact that early U.S. patents for a linear motor propelled train were awarded in the United States in 1905, Maglev railroad systems operated only in China, Germany, and Japan in the first decade of the 21st century.

The three underlying principles of Maglev technology are levitation or suspension, propulsions and guidance. Deriving from its technological principles, a Maglev rail system has three components which are a large electrical power source, metal coils lining a guideway or track, and large guidance magnets attached to the underside of the train.

How Maglev Rail Systems Operate

Maglev trains float on a cushion of air. In a Maglev system, magnets are installed on a vehicle's undercarriage and on a guideway a short distance away. Maglev guideways are made of steel, concrete, or aluminum which can be T-shaped, U-shaped, Y-shaped or box-beam. The magnets allow the vehicle to levitate between .039 and .93 inches above the guideway and electric power is supplied to the coils within the guideway walls, creating a system of magnetic

fields that pull and push the vehicle along the guideway. The electric current in the coils in the guideway walls constantly alternates to change the polarity of the magnetized coils. This change in polarity causes the magnetic field in front of the vehicle to pull it forward, while the magnetic fields behind the vehicle give it more forward thrust. Existing Maglev technology focuses on Maglev trains that promise dramatic improvements in rail systems if countries have the resources and political will to install them. Developers predict that Maglev trains will eventually link cities as distant as 1,000 miles apart.

Maglev Trains Compared to Conventional Trains

Electric powered and noncontact, the Maglev system does not rely on the wheels, bearings, and axles of the conventional rail systems. Maglev trains do not have the kind of engine used to pull conventional train cars along steel tracks. Since they are noncontact, weather does not affect Maglev trains and snow, ice, severe cold, rain or high winds don't slow them down or stop their operation.

The Maglev air cushion eliminates friction and this lack of friction and the aerodynamic design of the Maglev trains allows them to reach ground transportation speeds of more than 310 miles per hour, or twice as fast as Amtrak's fastest commuter train. The trains move more smoothly and quietly than mass transit systems with wheels. Also, Maglev



The Shanghai Transrapid Maglev train in a station in 2008. The only commercialized Maglev line as of 2013, this train is able to traverse nearly 19 miles in only eight minutes.

train systems can accelerate and decelerate more quickly than wheeled systems. Instead of using fossil fuels, Maglev trains are powered by electricity, and there is no need for signaling systems or whistles or horns on Maglev trains, because all systems are computer-controlled. No human operator could move fast enough to slow down or stop these systems, but two microwave towers are in contact with the Maglev trains at all times.

Currently operating Maglev trains have demonstrated minimal maintenance requirements, and the maintenance they do need is based on the number of hours of operation rather than speed or distance traveled. Unlike traditional railways, Maglev trains are not subject to the wear and tear of miles of friction on mechanical systems and do not incur the commensurate maintenance costs. Cheaper running costs give Maglev rail an advantage over conventional rail, and Maglev also offers better reliability, availability, and sustainability. There is one technical issue

with Maglev that does not affect traditional trains. Magnet reliability is typically lessened at higher temperatures, but new alloys and manufacturing techniques have produced magnets that can maintain their levitational force at higher temperatures.

Maglev trains produce less noise than a conventional train at equivalent speeds. The major noise source for Maglev vehicles comes from displaced air. Studies have indicated that Maglev noise levels should be compared to road traffic and rated accordingly, while conventional trains are judged at a different noise level. From an environmental perspective, Maglev trains cause less pollution than trains powered by fossil fuels. They are also more efficient people movers than passenger airplanes, transporting as many as 12,000 passengers per hour in each direction.

A major drawback of Maglev train systems is that they are not compatible with conventional track systems, requiring new infrastructure for their entire route. However, advocates argue that Maglev's completely separate infrastructure more than pays for itself because of its all-weather operational reliability and insignificant maintenance costs.

Several countries, including the United Kingdom, Canada, China, Germany, and Japan, have sponsored research and development programs into Maglev technology over the past two decades. Germany and Japan have each invested over \$1 billion to develop and demonstrate Maglev technology.

Maglev Trains in Japan, China and Germany

Japan's sleek bullet train system gained international fame in the 1960s, and more than 50 years later, the country is pioneering Maglev trains. In November 2012, Central Japan Railway Company (JR Tokai) unveiled a magnetic levitation train that can travel over 310 miles per hour. New trains scheduled to go into use in 2027 will link Shinagawa Station in central Tokyo with Nagoya, traveling at about 311 miles per hour. The extended plan is to have new trains connect Tokyo to Osaka by 2045, and Japan is also exploring the option of exporting its train technology.

Shanghai, a booming metropolis in east China, features the Shanghai Maglev Train (SMT), the world's first and only commercialized Transrapid Maglev train line. It runs from Pudong International Airport to Longyang Road Station, located at the intersection of Longyang Road and Baiyang

Road in Puong New Area. The entire journey takes only eight minutes to cover 18.6 miles.

Siemens and ThyssenKrupp of Germany built the train set in 2000 at a cost of \$1.2 billion. Local Chinese companies built the guideway. The Shanghai Maglev Transportation Development Co., Ltd. operates the Maglev Line, as well as the Shanghai Maglev Transportation Science and Technology Museum.

Engineers in the German company Transrapid International developed an electromagnetic suspension (EMS) system, called Transrapid. Even though German inventors helped pioneer this technology, Maglev trains have had slow going in Germany. Germany has a well-developed network of conventional high-speed trains, but the only Transrapid line in the nation so far is an experimental stretch in the rural northwest.

In this system, the bottom of the train wraps around a steel guideway, and electromagnets attached to the undercarriage of the train are directed up toward the guideway. This levitates the train about one-third of an inch above the guideway, keeping it levitated even when the train is not moving. Guidance magnets embedded in the body of the train keep it stable during travel. The train can reach speeds of 300 miles per hour.

During trial runs, Transrapid 08 carried passengers along a 19.8-mile test track running from Lathen to Dorpen, often reaching speeds of 280 miles per hour. In September 2006, the Maglev collided with a maintenance vehicle on the tracks near Lathen, killing 23 people. In March 2008, the German government announced it was abandoning plans to build a high-speed Maglev link with Munich airport because of spiraling costs. However, the transportation minister said that Maglev research and development would continue in Germany, and the country would continue to export Maglev technology.

The United States and Maglev Technology

On February 14, 1905, the U.S. Patent office awarded inventor Alfred Zehden a patent for a linear-motor-propelled train, followed by a second patent on August 21, 1907. G.R. Polgreen described an early modern type of Maglev train and was awarded his patent in 1959, as were Robert Goddard and Emile Bachelet. In 1968, James R. Powell and Gordon T. Danby were granted a patent for their design for a magnetic levitation train.

Under the High Speed Ground Transportation Act of 1965, the Federal Railroad Administration (FRA) funded extensive research into numerous forms of high-speed ground transportation through the early 1970s. In 1971, the FRA awarded contracts to the Ford Motor Company and the Stanford Research Institute to develop Electromagnetic and Electrodynamic systems, and these contracts produced the linear electric motor that is used by current Maglev prototypes. Federal funding for high-speed Maglev research in the United States ended in 1975, but research into low-speed Maglev continued until 1986.

Despite setbacks, advocates in and out of government continue to champion Maglev systems, which they say would provide transportation alternatives, in particular, for time-sensitive trips of 100 to 600 miles. In addition, Maglev systems would reduce air and highway congestion, air pollution, and energy use, and facilitate long-haul service at crowded airports.

In 1990, the National Maglev Initiative (NMI), a cooperative effort of government agencies, was established, including the FRA, the U.S. Army Corps of Engineers, and the Department of Energy. The NMI had the task of evaluating the potential for Maglev to improve intercity transportation, and developing guidelines to determine the role of the federal government in advancing this technology. The NMI identified several corridors extending hundreds of miles across the country that would benefit from Maglev trains.

Congress subsequently passed the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), adding an appropriation of \$26.2 million to identify Maglev system concepts to be used in the United States, as well as to assess the technical and economic feasibility of these systems. Studies were also ordered to determine the role of Maglev in improving intercity transportation. Congress appropriated an additional \$9.8 million to complete the NMI studies. Since the 1990s, however, studies and funding that would advance Maglev technology have largely stagnated.

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See Also: Green Transportation; High Speed Rail, Design and Technology of; High Speed Rail, Policy and

Planning of; Rail Transit Planning, Worldwide; Railway Automation Technology.

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Marine Transportation System

The U.S. Marine Transportation System (MTS), a network of waterways, ports, and interlocking land connections, is an initiative of the Maritime Administration, the Coast Guard, and 10 other federal agencies. These federal agencies, in partnership with nonfederal agencies, work to ensure a safe, environmentally sound, world-class Marine Transportation System. The MTS comprises 25,000 miles of navigable channels, the Great Lakes, the St. Lawrence Seaway, 238 locks, more than 3,700 marine terminals, and recreational marinas. It also includes 174,000 miles of rail and more than 45,000 miles of interstate

highway. More than 1,400 connections have been designated intermodal, which means that people or cargo must change transportation modes at a place where two or more forms of transport meet.

The U.S. Department of Transportation's Bureau of Transportation Statistics has estimated that the total value of marine freight will increase by 43 percent domestically and 67 percent internationally between 2010 and 2020. Ferry passenger transportation is growing rapidly because of traffic congestion on land, and use of the MTS by commercial fishing entities and the military is also expected to grow. Maritime transport must also be safely handled and balanced with environmental values to ensure that freight and people move quickly and efficiently to, from, and on American waterways. The MTS provides vital national security assistance by transporting and sustaining the American military. More than 90 percent of all equipment and supplies for the 1990 to 1991 Gulf War were shipped from strategic ports on inland and coastal waterways.

The MTS serves 78 million American recreational boaters who boat, fish, sail, canoe, and kayak, and its records illustrate the tremendous monetary boost that recreational boating gives to the American economy. The U.S. Coast Guard, as part of the MTS, takes a proactive approach in identifying potential causes of recreational boating accidents and deaths and setting attainable goals to reduce both. The MTS also supports the 110,000 commercial fishing and recreational vessels that together contribute \$111 billion to state economies. The more than 5 million American cruise ship passengers a year also come under the umbrella of the MTS.

The Marine Transportation System and the Environment

Marine Transportation System members strive to provide environmentally responsible modes of transportation. According to the Maritime Association, ships and barges have the fewest accidental spills or collisions of all forms of maritime transportation. Members of the MTS advocate environmental responsibility, including cleaning up polluted waterways, refraining from overfishing, and banning operations like dredging or trawling that damage the environment.

The U.S. Coast Guard and the National Oceanic and Atmospheric Administration (NOAA) are just two of the MTS agencies that work together to



The U.S. Coast Guard's Legend Class National Security Cutter Bertholf visits the San Diego Naval Base, November 12, 2008. It is estimated that the total value of marine freight will increase by 43 percent domestically and 67 percent internationally from 2010 to 2020. The Coast Guard facilitates this trade through its maritime security efforts and environmental activities, including monitoring oil, air, and plastics pollution; aquatic nuisance species transported by vessels; and related international agreements.

manage environmental disasters like oil spills and hurricanes. Both agencies assisted in the Deepwater Horizon oil spill cleanup in the Gulf Coast and along all affected shorelines.

Coast Guard men and women rescued 3,584 people and transported them to safety during Hurricane Katrina in 2005. In the 2011 Midwest floods, Coast Guard personnel deployed to support federal, state, and local agencies throughout the Midwest and southern United States to rescue people from the record floodwaters along the entire Mississippi River system. In Louisiana a Coast Guard unit, the Marine Safety Unit Baton Rouge, daily checked the Mississippi River for damage and assisted local people and businesses.

The Maritime Administration, part of the U.S. Department of Transportation, has played an important role in dealing with problems stemming from foreign aquatic species entering American waters through ballast water, including zebra mussels, rapa whelk, spotted jellyfish, and Asian carp. The Maritime Administration is cooperating with

other MTS agencies to monitor ballast systems without disrupting the flow of vessel transportation.

For several years, the Maritime Administration has partnered with NOAA and the U.S. Fish and Wildlife Service (FWS) to promote the development and demonstration of technologies to treat ballast water. Costs and difficulty of installing a full-scale treatment system for ship ballast water are drawbacks, but the Maritime Administration has offered its ships for limited shipboard tests.

National Security Assistance and Terrorist Education

Since the September 11, 2001, terrorist attacks on the United States, maritime security efforts have mainly focused on commercial vessels, cargoes, and crew, paying only limited attention to safety and basic law enforcement rules for smaller vessels. Gradually, though, MTS members have realized that smaller vessels are especially likely to be used for illegal immigration and by terrorists to smuggle weapons of mass destruction, narcotics, and other

contraband. Terrorists overseas have successfully used small boats to deliver waterborne improvised explosive devices.

Maritime authorities face the challenge of separating the thousands of legitimate mariners from the few who conduct illegal activities. The challenge is daunting because it involves nearly 13 million registered U.S. vessels, 82,000 fishing vessels, and 100,000 commercial small vessels. Many of these boats share waterways, ports, and bridges with commercial and military traffic, and they can easily access high-risk military installations such as petrochemical plants. The Homeland Security Act of 2002 divided the Coast Guard's mission between homeland security and non-homeland security. The Homeland Security Act identified ports, waterways, and coastal security as the first homeland security mission, and the commandant of the Coast Guard designated coastal security as the Coast Guard's primary focus alongside search and rescue. The Coast Guard's mission includes the protection of the U.S. maritime domain, the U.S. MTS, and those who live, work, and enjoy recreation near them. The Coast Guard also strives to prevent and disrupt terrorist attacks, sabotage, espionage, or subversive acts, and to respond to and recover from the terrorist attacks that do occur.

The Coast Guard also supports America's Waterway Watch, a public outreach program that encourages people to report suspicious activity to the Coast Guard or to other law enforcement agencies. Towboat operators, recreational boaters, marina managers, and other people who live, work, or play around America's waterways are in a unique position to keep waterways safe by keeping their eyes open.

The Maritime Security Response Team is a Coast Guard team highly trained in counterterrorism skills and tactics; its members are trained to be first responders to potential terrorist situations. The Coast Guard team tightens security measures against terrorists, conducts port-level counterterrorism exercises, and teaches Coast Guard counterterrorism procedures.

Coast Guard cutters, boats, helicopters, and shoreside patrols are part of maritime antiterrorism activities, and many Coast Guard activities support the Department of Homeland Security's Small Vessel Security Strategy. Twelve marine safety and security teams patrol security zones, conduct port state control boards, protect military installations,

ensure maritime security during major marine events, augment shoreside security at waterfront facilities, search for weapons of mass destruction, and participate in port-level antiterrorism exercises in their home and other ports.

In 2002, Congress passed the Maritime Transportation Security Act, citing the exposed and open nature of ports and their vulnerability to terrorist acts, which could cause a large loss of life and economic disruption. The act identified a special security risk to the cruise ship industry. The legislation called for improved inspection of containerized cargo, implementation of biometric identification procedures for individuals who have access to port facilities, and the securing of entry points and other areas of port vulnerability.

Coordinating maritime initiatives and policies as part of a larger system creates a more efficient MTS and overlapping domestic and international safety nets, layers of security, and effective vigilance, making it harder for terrorists to succeed.

The Coast Guard and Maritime Transportation Act of 2012

On December 20, 2012, President Barack Obama signed the Coast Guard and Maritime Transportation Act of 2012, creating new authority, responsibilities, and opportunities for the MTS and creating the U.S. Committee on the Marine Transportation System (CMTS). The purpose of the CMTS is to assess the adequacy of the MTS, promote its integration into the overall marine environment, and coordinate and make recommendations regarding federal policies that affect the MTS. The act confirms the membership in the Marine Transportation System of the Coast Guard and the CMTS and allows them to share resources and consult with other MTS members. The CMTS is required to report on the implementation of actions it has recommended in the *National Strategy for the Marine Transportation System: A Framework for Action* and to provide an assessment of the condition of the MTS.

Critical Issues Facing the Marine Transportation System

Even though the MTS is an efficiently operating network, it faces many future challenges. The number of recreational boaters is expected to grow by more than 130 million annually in the next 20 years. High-speed ferry transportation is growing rapidly

because of land transport congestion, and commercial fishing is expected to increase. Military reliance on the MTS is also expected to grow substantially.

American companies are facing a more competitive environment, and they must restructure themselves to serve larger and more demanding markets. Ports and other MTS operators also must meet more stringent requirements to successfully compete for American business. MTS ports and facilities must function more swiftly and less expensively while moving goods reliably and securely. Transportation providers must be ready to forge new business alliances and deploy new technologies and equipment to reduce the cost of moving goods and to meet the requirements of shippers. Future changes include constructing larger and faster vessels capable of carrying more than 6,000 20-foot containers, double-stack trains for transporting shipments over land, and advanced tracking systems.

The physical infrastructure and information systems that support MTS must be improved to adapt to changing needs. Infrastructure issues include dredging and marking harbor channels connecting U.S. ports to the world. Dredging requirements can be expected to grow because deeper waterways will be required for larger vessels. Nearly half of America's inland waterway locks and dams are at least 50 years old, and many locks are undersized for modern commercial barge operations. Modernizing locks and dams to regulate water flow and facilitate commerce is a necessary expense. Improving marine terminal capacity and access to rails, roads, and pipelines is also necessary to efficiently move goods across geographical areas.

Updating computer communications and navigational technologies to increase the productivity, safety, and security of the MTS is a necessary reform measure. Installing technologies such as intelligent transportation systems, differential global positioning systems, vessel traffic services, physical oceanographic real-time systems, and electronic navigational charts will bring systems into the 21st century.

The Marine Transportation System 2020

The vision of the private, state, local, and national agencies comprising the U.S. MTS is to make it the world's most technologically advanced, safe, secure, efficient, effective, accessible, globally competitive, dynamic, and environmentally responsible maritime system for moving goods and people. According

to people involved in federal legislation and state, local, and private MTS operations, aggressive, cost-effective technology development and deployment to ensure long-term competitiveness and continued cooperation and coordination are essential in achieving the MTS vision. The guiding principles essential to making this vision a reality include environmental, security, and commercial components.

Coastal water, estuaries, inland rivers, wetlands, and habitats are included in the MTS. Its users, from recreational boaters to commercial vessels and waterfront terminals, must work to protect and sustain the environment. Marine operations, maintenance, and investments should integrate environmental protection. Environmental quality is crucial for sustaining coastal and marine ecosystems, commercial and recreational fisheries, and the economic vitality of the MTS. Decision making and planning should acknowledge the interdependency of the MTS and the environment.

The MTS faces rising international organized crime and a growing number of rogue states and terrorists, all seeking to exploit vulnerabilities in the system. New funding methods for the MTS need to be explored and implemented. Federal funding, including user fees and private investment alternatives, should be investigated and coordinated public funding processes put in place.

Coordination at the national level consists of a new federal Interagency Committee for the Marine Transportation System (created through the expansion of the Interagency Committee for Waterways Management) and a Marine Transportation Agency National Advisory Council. The Interagency Committee for the MTS is the national coordinating body where federal agencies responsible for one or more aspects of the MTS discuss strategies to minimize duplicate efforts and coordinate overlapping functions. The Marine Transportation System National Advisory Council is composed of senior-level representatives from nonfederal organizations. Additional key elements of the MTS coordination framework include local and regional committees. People, workforce, passengers, and legislators, as well as state, regional, and local officials, are critical to the successful operation of the MTS and essential to the fulfillment of its vision for the future.

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See Also: Ferries; Harbors, Environmental Issues of; Harbors and Ports, Administration and Operations of; Inland Waterways, Freight Traffic and; Inland Waterways, Navigation of; Maritime Administration; Ships.

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Maritime Administration

The U.S. Maritime Administration (MARAD) is an agency of the U.S. Department of Transportation. Its mission is to improve and strengthen the U.S. marine transportation system and enable it to meet the country's environmental and security needs. The official who runs MARAD, known as the maritime administrator, works for the secretary of transportation. The maritime administrator is also

the chairperson of the Maritime Subsidy Board, the commandant of the U.S. Maritime Service, and director of the National Shipping Authority.

Established in 1950, MARAD deals with all aspects of waterborne transportation, promoting the use of waterborne transportation and ensuring its seamless integration with other segments of the transportation system. Responsible for the U.S. Maritime Service and the U.S. Merchant Marine, the agency works to maintain shipbuilding and repair services, ports, intermodal water and land transportation systems, and reserve ships for national emergencies. It provides services and sets the routes that are needed for foreign commerce, including the requirements of ships serving the routes. MARAD also conducts research and development activities in the maritime field and regulates the transfer of U.S.-documented vessels to foreign registries.

History of the U.S. Maritime Administration

MARAD traces its roots to the Shipping Act of 1916, which established the U.S. Shipping Board; this was the first federal agency with the mission of promoting maritime interests and regulating U.S. commercial shipping.

The Shipping Board created a naval auxiliary, naval reserve, and merchant marine. The Shipping Board also created the Emergency Fleet Corporation (EFC) just days after the United States officially entered World War I, to oversee ship construction and to acquire, manage, and operate ships. After the war ended, the Shipping Board continued to build ships until 1921, having produced nearly 2,300 ships. This surplus of vessels, in turn, created an industry depression. In 1928, the EFC was renamed the Merchant Fleet Corporation (MFC), and in 1930, the Department of Commerce absorbed the MFC and the Shipping Board and reinvented the two agencies as the U.S. Shipping Board Bureau.

The Merchant Marine Act of 1936 established the U.S. Maritime Commission, which assumed the duties, functions, and property of the Shipping Board Bureau, and was assigned the task of advancing and maintaining a strong merchant marine to support U.S. commerce and defense. The commission regulated ocean commerce, and designed and constructed 500 merchant ships over a 10-year period. President Franklin D. Roosevelt appointed

Joseph P. Kennedy Sr., father of future president John F. Kennedy, as the commission's first chairman.

When war broke out again in 1941, the construction program was in full swing, and the Maritime Commission's peacetime purpose changed, just as the Shipping Board's had in 1917. In 1942, President Roosevelt issued Executive Order 9054, separating the Maritime Commission into two agencies: the Commission to Design and Construct Ships and the War Shipping Administration (WSA), which would procure and operate them. Working closely together between 1941 and 1946, the Maritime Commission and WSA built nearly 6,000 merchant vessels and naval auxiliaries. The WSA was also managing the operations, repair, and maintenance of thousands of ships. In 1946, the government dissolved the WSA and transferred its operations back to the Maritime Commission. Thousands of ships were sold or scrapped under the Merchant Ship Sales Act, but the Maritime Commission retained a group of reserve ships called the National Defense Reserve Fleet.

In 1950, following President Harry S. Truman's recommendations in Reorganization Plan No. 21, Congress dissolved the U.S. Maritime Commission, dividing its duties between the newly created Maritime Administration and the Federal Maritime Board (FMB) and assigning both organizations to the U.S. Department of Commerce. In 1961, as part of Reorganization Plan No. 7, the FMB became an independent regulatory agency and was renamed the Federal Maritime Commission. The subsidy function of FMB returned to MARAD as the Maritime Subsidy Board, reporting independently to the MARAD Administrator. The 1961 reforms are the foundation of MARAD's 21st century organizational structure. In 1981, MARAD was transferred to the Department of Transportation as part of a consolidation of all federal transportation programs into one cabinet-level department.

The U.S. Merchant Marine

Established in 1938 under the provisions of the Merchant Marine Act of 1936, the U.S. Maritime Service (USMS) was given responsibility for training people to become officers and crew members on ships of the U.S. Merchant Marine. This service is now under the authority of the MARAD, with the Maritime Administrator acting as the commandant. This person also serves as the director of the

National Shipping Authority and the chairperson of the Maritime Subsidy Board. The commissioned officers of the USMS serve as administrators and instructors at the U.S. Merchant Marine Academy and the maritime academies.

Both the U.S. government and the private sector have operated ships in the merchant marine fleet, which comprises all vessels engaging in commerce or transportation of goods and services in the country's navigable waters. The merchant marine transports cargo and passengers during peace time, and the U.S. Coast Guard, the Department of Transportation and the Maritime Administration regulate the ships. People who serve in the merchant marine are called mariners, sailors, commercial sailors, or seafarers.

The merchant marine also functions as an auxiliary in war or national emergency by transporting goods or materials for the armed forces, serving in every U.S. war since 1775. The merchant marine played a pivotal noncombat role in World War II, delivering troops and supplies for the military. During World War II, the federal government controlled the cargo and destinations of merchant ships and trained people to operate the ships through the USMS.

In the 21st century, MARAD is still in charge of maintaining a strong merchant marine. To train and educate those who are operating the fleet, MARAD operates the U.S. Merchant Marine Academy at Kings Point, New York, and provides funding and maintains training ships for six state maritime academies, including the State University of New York Maritime College in the Bronx, New York; Massachusetts Maritime Academy in Buzzards Bay, Massachusetts; California Maritime Academy in Vallejo, California; Maine Maritime Academy in Castine, Maine; Texas Maritime Academy in Galveston, Texas; and the Great Lakes Maritime Academy in Traverse City, Michigan. MARAD also offer maritime training, degrees, and certification.

The National Defense Reserve Fleet

Established under Section 11 of the Merchant Ship Sales Act of 1946, the National Defense Reserve Fleet (NDRF) maintains ships that can be called into service for 20 to 120 days for national defense and national emergencies. MARAD manages the NDRF, which is made up of mothballed ships,

mostly merchant ships. The NDRF also logistically supports the military when necessary.

Vessels that are deemed valuable for military or logistical reasons are placed in a preservation program designed to keep them in the same condition they were in when they entered the fleet. Their internal spaces are dehumidified to slow metal corrosion and inhibit mold growth and mildew. Workers send electric current to exterior underwater portions of the hull, which creates an electric field, suppressing corrosion and preserving the hull's surface. Workers generally do not paint the outside of the ship or perform cosmetic alterations, because their focus is maintaining operation of the vessels, not aesthetics.

NDRF vessels are moored at fleet sites on the James River in Virginia and in Beaumont, Texas. Other vessels are gathered at Suisun Bay, California. At its peak in 1950, the NDRF was in charge of 2,277 mothballed ships, but by 2000, only 274 were in reserve. In July 2007, the 230 ships in the reserve fleet were mostly dry cargo ships, along with some tankers, military auxiliaries, and other kinds of vessels. The Suisun Bay location contained 324 ships in 1959. By 1999, the number had fallen to about 250, but the vessels had created an accumulated pollutant problem. Paint containing lead, copper, zinc, barium, and other toxins continuously flaked off of the hulls and superstructures of many of the ships. By June 2007, the ships had shed about 21 tons of toxic paint debris, which settled in the sediment of Suisun Bay, MARAD personnel estimated. MARAD identified 52 ships as problematic and scheduled them to be removed and recycled by September 2017.

Through special legislation, the NDRF program has the ability to lend or give historic artifacts or transfer entire ships to maritime heritage organizations.

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See Also: Harbors, Environmental Issues; Harbors and Ports, Administration and Operations of; Inland Waterways, Planning and; Maritime Industry; Ships; World Container Ports.

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Maritime Industry

Understanding the modern maritime industry necessarily begins with coming to terms with its dimensions. It is a cliché factoid of middle school social studies that 70 percent of the world is covered with water, oceans, inland water systems, rivers, and lakes. The fact that 80 percent of that global water system is navigable creates a maritime industry that, despite the relatively slow speeds of ships, is the largest and most efficient transportation system humanity has ever constructed. Few people not directly involved with maritime transportation grasp the vastness of the world’s waterways—for example, a container vessel—a massive (most more than 20 stories high) but relatively common ship used to transport goods, foodstuffs, and minerals in bulky truck-sized containers—can travel the equivalent of a trip to the moon and halfway back in a normal year.

More than planes or trains or trucking, the maritime industry provides critical connections between nations, between businesses, and between production facilities and consumer markets. And given the industry’s use of the natural energy and sheer power of waterways and the intricate connections of water systems that provide access to virtually any market anywhere, the maritime industry is the cheapest mode of transportation available for both goods and people. What is sacrificed in speed—the average cargo-carrying vessel today travels just under 30 knots per hour, or about 45

miles per hour—is gained in the accessibility and reach of the world’s waterways.

History

In many ways, more than 3,000 years ago, the maritime industry provided a kind of template for the international networking constructed over the last generation through the reach of the Internet. Nearly four millennia before the advent of modern transportation systems—the railroad, the internal combustion engines, and the airplane—began to reconfigure the world into a global market, the Egyptians first tested the viability of a maritime economy, and subsequently, virtually every significant civilization in antiquity (the Greeks, the Romans, the Phoenicians, the Japanese, the Chinese) relied on sailing to provide the most economically sound system of transporting goods and people, relying on shipping not only to secure global markets but also to establish a military presence in far-flung outposts.

In post-Renaissance Europe, the storied rise of the great sea powers and the nearly two centuries of global exploration, militarization, and colonization—most notably the vast navies of Spain, Portugal, England, France, and the Netherlands—redefined the importance of the maritime industry. With the advent of steam-powered engines and the emergence in the mid-19th century of a global maritime industry that did not rely on the vagaries of wind to power its ships, the maritime industry established itself as the most dominant transportation system ever conceived.

Today’s Maritime Industry

But if it is the oldest transportation system, shipping is as well central to the 21st century global economy. Today’s maritime industry very much maintains a global presence; conservative estimates suggest that upwards of 90 percent of consumer goods worldwide depend either in their production or in their distribution on transportation through shipping.

Given that the maritime industry must deal with multiple governments with a variety of transportation codes, tax systems, regulatory agencies and bureaucratic protocols, international shipping conglomerates are notoriously secretive about their operations, the ownership of their vessels, the size of the crews they staff, the number of licensed ships in their fleet, and even the cargo they carry.

Although exact numbers are difficult to come by, *Clarkson's Shipping Intelligence Weekly*, the bible of the industry, places the number of cargo-carrying ships globally at just under 60,000. Factoring in other types of smaller ships (harbor patrols, cruise liners, passenger ships, small merchant vessels, pleasure crafts), the number is closer to 90,000.

Data on crew sizes are difficult to establish as well. Although officers and administrative staffs are among the most highly educated and best paid transportation workers in the world, the vast majority of crew members are the barely educated, undocumented (and underpaid) poor from a variety of Third World countries who must work in difficult and dangerous conditions and who are routinely exposed to illnesses given that the crews work and live in the same environment often for months at a time in confined spaces with shared water and waste systems, inadequate ventilation, minimum attention to moderating temperatures, and with access to basic medical services at best.

Because so much space in ocean-going vessels must be given over to accommodate ever-increasing metric tons of cargo, little thought is given to providing habitable space for the crews. International health organizations routinely rate ships among the most hazardous work sites; workers are prone not only to accidents and falls but also to injuries from electrical shock, chemical exposure, excessive noise, and burns, as well as the physical, emotional, and psychological stress inevitable during prolonged voyages in open water away from family.

Related Businesses

Perhaps more difficult to measure than the reach of the shipping industry is the variety of services and businesses, both at sea and on shore, that come under the heading of the maritime industry. Most obviously, the industry includes those businesses involved with the design and production and acquisition of the ships themselves as well as the crews that maintain their service (and travel with the vessels) and the land-based industries that provide component parts for the ships. In addition, there is a vast superstructure of global transportation companies that monitor the shipping lanes, track and direct traffic and weather patterns, and maintain safe routes in the ever-changing environment of the sea.

There are international legal services specializing in maritime law that protect both the shipping interests as well as companies who rely on shipping and the passengers who use the services. Factor in the banks, insurance companies, and the network of services provided routinely at ports and harbors and terminals from traffic management to customs agencies to loading crews and maintenance staffs, and the dimensions of the maritime industry begin to emerge. Of course, this does not factor in the vast military dimension of the maritime industry (data on that is of course difficult to come by) or the large armada of research vessels that daily are gathering volumes of scientific data on the conditions of the world's water ways, or the small-vessel industries such as fishing and public transportation (water taxis, ferries, and bus-boats), or the hundreds of both floating and permanent drilling rigs and the network of services that maintains them.

Given the vast reach of the maritime industry, measuring its actual economic dimension is at best problematic. Entire national economies such as Denmark and Japan and Australia as well as a host of archipelago nations such as the Philippines, Indonesia, the United Kingdom, and Taiwan, almost entirely rely on their maritime industry; more than two million jobs are tied to the maritime industry in Europe alone. The production value of China's maritime industry, itself considered in its infancy, accounted for more than \$800 billion in 2012: nearly 10 percent of that country's entire economy.

Types of Vessels

If the reach, economic impact, and scale of the maritime industry are difficult to measure with any exactness, the types of vessels considered part of the maritime industry's profile are a bit clearer. In general, 10 types of vessels make up the maritime industry. Bulk carriers are the most familiar large boats, with cavernous watertight hulls that are, in turn, filled with coal, grains, or oil. Containers, as their name suggest, transport mineral resources, foodstuffs, and other goods in large containers about half a football field long. Refrigerator ships transport perishable foodstuffs, dairy products, and fruits and vegetables. Vehicle ships, also known as roll-ons and roll-offs, transport cars, trucks, airplane parts, and even train cars. Oil tankers are responsible for transporting not only fossil fuels

but also chemicals and natural gas in pressurized containers. On a smaller scale, easily recognized flat-top barges transport goods on interior lakes and river systems. Tugboats maintain traffic control in busy international harbors by pushing and redirecting large carriers to permit maximum efficiency for incoming and outgoing ships. There are numerous small-business vessels, most prominently fishing boats, that, despite their relatively small size, account for significant percentages of local economies. At the far end of the scale are the passenger vessels, both the transportation vessels associated with public transportation needs in cities and island nations and the burgeoning international tourist cruise industry.

Challenges

Although transportation systems analysts believe that the maritime industry is very much a part of the 21st-century global market—like the Internet a macroeconomic environment that will be instrumental in providing stable growth for national economies—the industry faces enormous challenges in the new century, most prominently in response to rapidly dwindling fossil fuel supplies and the effects of global warming and climate change that have in the last generation grown to alarming dimensions. In response, transportation systems analysts project that the maritime industry, in addition to investing in the construction of more vessels, must address the design of the ships as well, particularly large ocean-going transport vessels. Making these critical ships both larger and lighter would enhance the delivery potential of the maritime industry; nautical engineers have determined that doubling the size of a ship triples its cargo-carrying capacity.

Ships within the next generation must also begin to rely less on fossil fuels; the most attractive alternative is nuclear powered engines, although their cost is currently prohibitive and there are enormous safety concerns. Given that fossil fuel dependency is the most likely scenario at least for the next half century, advocates of energy use point out that cutting-edge engine technology needs to make the current fleet of transport ships quicker, their propulsion more engaged. In addition, shipping analysts vigorously promote manning major ports of call with additional work crews to cut downtime for global carriers—container ships, which provide most of the shipping industry work,

can spend more than half a year in port undergoing maintenance and being loaded or unloaded.

Proponents of the maritime industry offer far broader options than ship design. Construction and upkeep of canals, critical in threading waterways and providing more efficient transport options, lag far behind needs; often canals suffer infrastructure fatigue, surviving on basic maintenance because of government interference, downsized economies, or labor uncertainties. Major harbors will need to be re-examined and in many cases dredged to permit deeper waters in an era of shrinking sea levels.

In the first decade of the new century, for instance, states along the Great Lakes, particularly Michigan and Minnesota, began an aggressive (and expensive) campaign to dredge major ports and canals to improve navigability. More potentially impactful than increasing ship size and speed, however, are long-term plans to convert close to 40 percent of individual ship operations to automation by 2030. Automation has already aggressively improved harbor service, providing efficient around-the-clock maintenance of busy ports and better regulating the loading and unloading of boats. Transportation specialists see as inevitable, however, that automation on board ship will eventually allow shipping companies to downsize crews, converting navigation systems, security systems, and maintenance systems to permit companies to cut more than 25 percent of the current workforce.

Conclusion

Although the realities of the world's maritime industry lack the romantic aura of classic seafaring clichés, and despite the evident advantages in the speed of other transportation systems, transportation systems analysts perceive the global shipping industry, because it is relatively cheap and because it is comparatively environmentally friendly, as vital in the new century's evolution into a global economy.

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See Also: Container Terminals; Containerization/ Container Shipping; Dredging; Globalization; Harbors, Design and Engineering of; Harbors and Ports,

Administration and Operations of; Ships; World Container Ports.

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Metropolitan Planning Organizations

Metropolitan planning organizations (MPOs) were established as a part of the Federal Aid Highway Act of 1962. They play a significant role in transportation planning and regional governance across multijurisdictional metropolitan areas with populations of 50,000 or more. The roughly 400 MPOs in operation vary considerably in organizational structure, including size and composition of membership, planning boundaries, level of technical expertise, funding levels, programs and responsibilities, and standing within their regional structure.

This variety is by design, as federal legislation leaves much flexibility. Latitude is given for MPO structures to facilitate the most efficient and representative form of metropolitan transportation planning, given the inevitably unique features of geographic and institutional context. Diversity of form and function contributes to planning effectiveness, as MPOs serve a range of metropolitan areas, from newly designated urbanized areas with a few jurisdictions in their metro area to large multijurisdictional regions with many independent municipalities.

MPOs increasingly share regional planning responsibilities with the states. This shift in planning roles in recent decades was intensified by the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. However, many challenges still persist, especially as they relate to regional and intergovernmental cooperation.

Most MPOs are housed in and staffed by one of their member jurisdictions. Otherwise, they may be located within a regional or state agency. Some are part of regional planning councils or regional councils of governments, but others function as independent, free-standing organizations. At a minimum, the MPO is required to have a governing board, a technical committee, and a citizens' advisory committee, but some have additional committees, such as freight or transit advisory committees.

The MPO governing board adopts and endorses regional transportation plans, approves budgets and agreements, adopts rules, and oversees MPO operations. In practice, a typical MPO board is geography-based, comprising representatives of localities in the region. These board members are mostly appointed and consequently may not equally represent all interests in the region. The citizen advisory committee brings citizen participation to transportation planning.

The primary role of an MPO is to ensure that transportation decision making includes consideration of all the transportation needs of the metropolitan area, along with consideration of their consequences for land use, housing patterns, and economic development. Charged with addressing the broad spectrum of stakeholder needs, the MPO works collaboratively with local communities, governments, and transportation agencies to facilitate the meaningful involvement of the public.

To fulfill their responsibilities, MPOs assume a leadership role in developing the short-term Transportation Improvement Program (TIP) and Long-Range Regional Transportation Plan (LR RTP). The latter allocates federal funds for transportation projects within the region for 20 years or more. Among its obligations, the MPO is required to obtain citizen participation to develop, maintain, and propose the TIP and LR RTP. By law, these plans must be fiscally constrained and must link projects to revenue sources. The MPO presents these plans to the state, and then negotiates with state officials the ultimate project list for the region.

As a result of this partnership approach, the state is compelled to adopt some, but not necessarily all, of the planning suggestions from once-weak regional or local entities or jeopardize federal funding. In this way, the federal government places authority directly in the hands of the MPO. The MPO must find a balance between its relationship with the state and multiple relationships in its regional network of localities and community stakeholders.

MPOs in Transportation Planning

The Federal Aid Highway Act of 1962 mandated that states create MPOs and grant them responsibility for comprehensive, cooperative, and continuing (“3Cs”) planning. However, the actual role played by MPOs in transportation planning was somewhat limited. It was not until the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 that MPOs became securely integrated into transportation planning.

ISTEA had several provisions to strengthen the role and authority of MPOs in coordinating regional transportation planning. Through ISTEA, MPOs were, in effect, recreated as umbrella organizations to coordinate transportation programs within a multijurisdictional region, engage citizens, and facilitate discussion among stakeholders as part of a bottom-up transportation planning process. The basic framework for metropolitan decision making, as established by ISTEA, gives the MPO lead responsibility but mandates partnerships with the states and other stakeholders.

By expanding the role of MPOs, the federal government decreased the decision-making power of the state and empowered localities to operate through the MPO to devise a cohesive transportation plan for the region. Successor federal legislations (such as TEA-21, SAFETEA-LU, and MAP-21) continued the bottom-up model of regional transportation planning, thereby maintaining the significant role of MPOs.

MPO Relations With State Governments

The state, regardless of its traditional power over localities, must cooperate with the MPO in transportation planning. Yet, the MPO must cooperate with the state. Even though the MPO is empowered with more authority in transportation planning, it is still dependent on its relationship and coordination with the state. The state ultimately has more

overall power because it can easily work to veto a regional plan.

When ISTEA was passed, state transportation agencies were generally not in favor of bottom-up planning and MPO involvement, and they were displeased at the states’ diminished power in transportation decision making. As a result, MPOs sometimes had difficulty obtaining necessary information from the state in forming their plans. Budget information has been particularly difficult to obtain from states, making it challenging for the MPOs to effectively plan. Although the states comply when asked to do so, they are not always forthcoming with the necessary information, which increases the burden on the MPO. Regardless of the power given to the MPO under federal law in the planning process, all funds funnel through the states from the federal government to the localities. Power ultimately resides within the purse strings, where MPOs and state transportation agencies are hardly equal, but by law, the role of the MPO cannot be eliminated or significantly minimized.

Inter-Jurisdictional Cooperation and Planning

Under ISTEA, the MPO must collaborate with other planning entities regarding land-use planning, air quality and other environmental issues, and economic development. Yet, the MPO only has legal authority to provide transportation planning and related land-use planning.

Within metropolitan areas, individual jurisdictions can have differing, sometimes competing, interests. For example, cities reliant on mass transit tend to emphasize expansion of transit and the demands of the transit sector. The suburbs are more likely to seek more lane miles of highway. Too often, representatives from central cities and outer suburbs fail to come together for the good of the region but pursue instead the best deal for the locality they represent.

MPOs tend to emphasize automobile traffic, and very few MPOs include representatives from other modes, such as freight, airports, and rail. As a result, MPO boards tend to under-represent central cities and inner suburbs, and over-represent suburban interests. This can also produce under-representation of certain racial and ethnic groups, and such representational issues can significantly undercut the authority of MPOs.

Successful MPOs

Research has identified several characteristics of effective MPOs, including strong leadership, staff competence, credibility, quality public involvement, development of a regional ethos, streamlined and efficient processes, cooperative relationships with state transportation agencies, and accountability to members. Three of these characteristics are most crucial: highly competent MPO staff, high credibility, and strong leadership.

Competent staff is needed to ensure effective transportation planning, which is both complex and highly technical. To balance many competing demands during transportation planning and respond effectively to a range of interests, strong, dynamic leadership is essential. When leaders and staff are not held in high regard, they lose their credibility, and stakeholders lose trust in the planning process. The state will then be less likely to take the MPO's recommendations seriously. However, no matter how well-organized, competently staffed, and effectively run, all MPOs face the daunting challenges that are part and parcel of operating within a wide regional and intergovernmental context. With few exceptions, multijurisdictional transportation plans are a product of lengthy discussion and negotiation.

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See Also:

Intermodal Surface Transportation Efficiency Act; Public Participation in Transportation Planning; Regional Transportation Planning; Regional Transportation Planning Organizations; Regional Transportation Plans; 3-C Planning Process; Transportation Improvement Programs; Transportation Planning; Transportation Planning and Politics; Urban Transportation Planning Process.

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Microsimulation Models

Microsimulation (or microscopic) traffic simulation models use a detailed description of the movement of each individual vehicle in order to model traffic at a very detailed level. Microsimulation software is often used to evaluate traffic information, management, and control systems. Microsimulation models represent all related systems that affect traffic, such as traffic control and traffic guidance. Traffic control includes fixed and actuated traffic signals, ramp metering, and restricted access lanes and facilities.

In order to model the response of the drivers to information, microsimulation models provide facilities to represent information dissemination devices, such as variable message signs, and models to capture the response of the drivers to the presented information. As microsimulation models act as the test-beds for intelligent transportation systems and in-vehicle technologies prior to their deployment, microsimulation models sometimes also include facilities to model such systems as advanced driver assistance systems (ADAS), vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems, and pricing strategies.

Different types of vehicles are also modeled, including passenger cars, commercial vehicles, powered-two-wheelers, public transport vehicles, and emergency vehicles, as well as different types of drivers. Modeling of pedestrians is a more difficult challenge, but most commercial microsimulation software has begun integrating detailed pedestrian simulation components. The ultimate goal is to

model interaction among all of the various modes, such as how buses and trams interact with passenger vehicles, or how all motorized vehicle modes interact with pedestrians and bicyclists.

Microsimulation models have been developed for more than 60 years, and a large number of mature microscopic models are widely used today, including commercial software such as AIMSUN, PARAMICS, TransModeler, and VISSIM; software supported by authorities, such as CORSIM, and academic- and research-oriented software, such as DRACULA, MITSIMLab, and sumo. One of the key prerequisites of microsimulation models is their detailed network representation. The information that is required when representing a traffic network for a microsimulation model is much more detailed than it would be for a less detailed model, such as a mesoscopic or macroscopic model. Typically, besides links, nodes and lanes, the information that is required includes lane connections, turning movements, and location and settings of traffic control devices.

Driving Behavior

Driving behavior in microscopic simulation models transcends three levels: (1) a strategic level in which the driver decides how to traverse the network to reach the destination, which is commonly modeled using route choice models; (2) a tactical level, in which the driver attempts to implement a strategic plan, such as determining the appropriate lane changes; and (3) an operational level, in which the driver performs the actual maneuvers, such as gap acceptance and acceleration, that will enable the necessary tactical decisions.

In terms of the strategic level, some of the initial models did not represent paths but used instead intersection turning proportions to determine vehicle movements across the network. Therefore, these models were not suitable to model route guidance applications.

However, modern traffic microsimulation systems have graduated to the loading of demand, using origin-destination tables, and the use of route choice models (usually logit-type, discrete choice models) to determine the paths that the vehicles follow as they traverse the network. If information is provided to the drivers, then these models also consider how the drivers respond to this information.

Acceleration

The acceleration of a driver depends on several parameters, including characteristics of the driver, the vehicle, and the road geometry, as well as surrounding traffic conditions. In general, acceleration models can be classified into (1) car-following models, which describe the behavior of drivers in response to the behavior of the preceding vehicles and (2) general acceleration models, which describe driving behavior even in non-car-following conditions.

Car-following models were developed in the early 1950s by Reuschel and Pipes, who developed simple linear models of car-following behavior. More elaborate models were developed in the late 1950s by the General Motors Group, based on comprehensive field experiments. This line of research led to the development of a family of car-following models that postulate that the behavior (response) of a driver is determined by the behavior (stimulus) of the leading vehicle.

These models at time “ t ” follow this general form: $\text{Response}(t+T) = \text{Sensitivity} \times \text{Stimulus}(t)$, where T is a time-lag corresponding to the following-driver delay; for example, the time to assess the stimulus from the preceding vehicle and respond to it. This general family includes several types of models based on a number of variations: (1) type of response, such as speed or acceleration; (2) type of stimulus, such as speed, distance, or acceleration; and (3) sensitivity of the following driver. Simple models of this family have been criticized because they may lead to unrealistic or inconsistent traffic conditions.

Depending on the formulation of each of these terms, models can overcome these limitations and result in conditions that are consistent with macroscopic traffic theory. Still, there are some limitations with this family of models, because they assume that drivers follow the preceding vehicle even when the spacing between them increases, and they also assume perfect perception of the stimuli and perfect reaction to them.

Several other families of models have also been proposed to address these limitations, including the psycho-physical models, which introduce a perceptual threshold that defines the minimum value of the stimulus following drivers can respond to. Although acceleration and car-following models represent a mature field, there are still new models being developed, such as rule-based models, the intelligent driver model (IDM), and mixed-flow models.

Lane Changing

Lane changing behavior is another important part of microsimulation that has received considerable interest, although less interest than that of acceleration behavior. A common distinction is to classify lane changes as mandatory and discretionary. Mandatory lane changes are performed when the driver must change lane in order to, for example, exit at an off-ramp, avoid entering a restricted-use lane, comply with lane-use signs, or avoid an incident.

Discretionary lane changes, in contrast, are the result of a decision by the driver who perceives the driving conditions at the target lane are preferable to staying at the current lane. An inertia term to changing lane can be considered when evaluating the perceived value of each lane.

K. I. Ahmed has developed a general lane-changing model framework that captures mandatory and discretionary lane-changing behavior. The lane-changing process is modeled in three levels: (1) decision to perform a lane change, (2) choice of the target lane, and (3) decision to accept a gap in the target lane. The model allows different gap acceptance parameters for discretionary and mandatory situations. Variants of these models also exist, such as forced merging models, which describe the behavior of drivers who need to make a lane change in heavily congested situations in which no acceptable gaps naturally exist.

Gap Acceptance

Besides lane changing situations, gap acceptance becomes relevant in various situations in microsimulation, such as unsignaled intersection behavior models. Gap acceptance models are typically formulated as binary choice problems, in which the driver either accepts or rejects a given gap. This decision is based on an unobserved critical gap, which, in general, would vary in the driver population. This process can be enhanced with an impatience function to mimic the fact that a driver who has already passed on a number of gaps might become more impatient and frustrated and accept a smaller gap than those already rejected. One practical way to model this is through a decaying critical gap function, in which critical gaps decay with waiting time or the number of rejected gaps. Ahmed specified and estimated models that jointly model lane changing and gap acceptance.

Integrated Models

Modeling lane changing, gap acceptance, and other decisions independently implies that drivers perform these tasks in isolation. In reality, however, drivers may adapt one aspect of their driving behavior to facilitate another task. For example, a driver might decelerate, not because of the behavior of the preceding vehicles but in order to perform a lane-changing maneuver.

Integrated models that unify the elemental microsimulation models have therefore been developed to address these limitations. For example, researcher T. Toledo presented a framework integrating short-goals, short-term plans, and tactical maneuvers. The process is as follows: the driver develops a short-term goal (for example, to change lane) and devises a short-term plan (for example, determine a target lane) to achieve that goal. The short-term plan is realized through a maneuver. A sequence of steps might be required to accomplish that goal; for example, the driver might need to first accelerate in order to reach an acceptable gap between two preceding vehicles before being able to perform the desired lane-changing maneuver. Depending on the model formulation, these decisions might be sequential, conditional, or nested.

Limitation and Challenges

Microsimulation models behave well in many situations and provide valuable tools in which new systems, such as intelligent transportation systems, can be evaluated and optimized prior to their application and deployment. However, there are situations that cannot be easily modeled by microsimulation models.

Road parameters that might affect traffic conditions are often not well modeled. One such example is road geometry, where the impact of the lane width and roadway gradient are usually not considered. Also, vehicles are assumed to move in a specific lane, and their lateral movement (which, in reality, does play a role) is usually ignored.

This may not be a big problem in situations where lane discipline is followed. However, when lane discipline is relaxed, which occurs in many developing countries, a specific link might, in effect, have a varying effective number of lanes (for example, four or five vehicles might squeeze side-by-side on a three-lane road). This flexibility, however, cannot be captured by conventional microsimulation models.

Further, modeling of pedestrian flow, as well as two-wheelers, is also further behind the modeling of cars. This might not represent a major concern in Europe or the United States, but in certain developing countries where a large fraction of traffic may be composed of two-wheelers and nonstandard-sized vehicles, the ability of standard microsimulation models to reflect reality could be compromised. Naturally, new flexible-lane microsimulation models are being developed in response to these needs.

Modeling road safety has become a very important research and policy topic, and microsimulation models are attractive tools for modeling road safety. However, there are some challenges that limit their widespread use. An important limitation is that most well established car-following models are inherently crash free; that is, the following vehicle would stop before crashing into the preceding vehicle. (Models that overcome these limitations are being developed.) Still, the evaluation of the safety conditions can be performed based on secondary proxy measures, such as the time-to-collision, the distributions of the acceleration or speed, and the extreme acceleration and speed values.

Calibration and validation of microsimulation models are more demanding than that of mesoscopic and macroscopic models, because they typically include a much larger number of parameters and require more data. The overall cost of developing a microsimulation model (including time, resources, and data) is typically much higher than it would be for developing a mesoscopic or macroscopic model. Therefore, the decision on which type of model will be used for a specific application should carefully weigh the benefits of the additional granularity and detail versus the higher costs.

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See Also: Networks Modeling; Route Assignment Models; Traffic Simulation; Transportation Modeling and Planning Software; Travel Model Calibration; Travel Modeling/Simulation.

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Mixed-Mode Transit Systems

Mixed-mode transit systems, in which two or more modes of transportation are employed, seek to merge the benefits of various choices available to create a journey that is greater than the strength of its parts. Many mixed-mode transit systems seek to reduce reliance on the automobile and instead to encourage travelers to use a variety of other options, which may include walking, bicycling, rail, ferry, or other modes of transportation. The combination of two or more modes of travel also serves to offset the relative deficiencies of individual methods. As interest in sustainable practices continues to grow, mixed-mode transit systems will undoubtedly continue to play a role in transportation planning and policymaking decisions.

Background

Since the advent of automobile travel, many of the formerly popular travel modes have fallen into disfavor. While certain options used before the popularity of automobiles, such as the horse and carriage, have become marginalized, other modes of transportation—such as rail, bicycling, walking, and buses—are less environmentally harmful and still readily available. It becomes the mission of policymakers and planners to devise ways to encourage the public to

use modes of transportation that are more sustainable, even though they might not be as convenient as the door-to-door service offered by the automobile. To encourage commuters to leave their automobiles, alternative transportation options must be devised that are practical and cost-efficient.

Mixed-mode transit systems combine a variety of extant transportation options with one another to create a transportation option that is less damaging to the environment while also remaining convenient to the traveler. Existing travel modes, whether light rail, bus lines, roads or sidewalks, are used together to reduce the traveler's dependence on the automobile. Because many metropolitan areas are composed of multiple jurisdictions and decisions involve multiple agencies, mixed-mode transit systems require cooperation between different groups with authority to make decisions. In order to entice travelers to use the mixed-mode transit system, governments and agencies may offer such benefits as free parking, reduced fares, and other incentives to travelers using their systems.

Mixed-Mode Commuting

In many metropolitan areas, train or light-rail systems are the fastest and most efficient means to

move travelers. When mixed-mode transit systems are able to get travelers to eschew the single-passenger automobile and instead take all or part of their journey by train or light rail, the system reduces congestion, cuts down on pollution, and encourages environmentally sustainable behavior. Some mixed-mode transit systems seek to eliminate the automobile from most journeys, while others merely look to reduce its use. The goal set by a given transit system will depend upon commuter behaviors before the mixed-mode initiative is begun. Different scenarios play out better in different locations and with different groups, making planning essential.

Automobile travel is highly popular with commuters for a variety of reasons. Some of these reasons are unique to the individual, such as convenience and personal preference, but others have been greatly influenced by societal actions, such as the underpricing of the costs of automobile travel through federal and state tax subsidies to roads and freeways. As a result of these subsidies, the true costs are borne not by the user, but by society as a whole.

Proponents of mixed-mode transit systems use both incentives and deterrents to decrease commuters' reliance on the automobile. Incentives might include providing convenient parking for a



This glass bikestation outside the Union Station rail line in Washington, D.C., is a form of bike-and-ride system meant to encourage mixed-mode transit. The building provides safe storage for more than 150 bicycles at a time so that bicycle riders may make use of trains, the metro, and other transit nearby or visit surrounding areas on foot.

reduced price, giving transit users reduced fares, or making other changes that make mixed-mode transit more convenient and attractive. Deterrents could include reducing travel speed through speed bumps, reducing parking through various restrictions, prohibiting motor vehicles at certain times of the day, or enacting tolls for use of the roads leading into or through the central business district. The complexity of the incentives and deterrents will depend on how well the mixed-mode transit system is meeting its ridership goals.

Park-and-Ride/Kiss-and-Ride Systems

One of the most common ways planners and policymakers encourage mixed-mode transit is through implementation of a “park-and-ride” system. Park and ride is a way of encouraging commuters who would otherwise drive to their location to take a train, light rail system, or bus for part of their journey. Planners and policymakers provide car parking lots at train, light rail, or bus stations, permitting commuters to leave their cars for free or at a reduced charge. A slightly different method of encouraging the use of trains, light rail, or buses is termed *kiss and ride*. This is a designated area, close to where passengers board the transit mode, that allows the commuter to be dropped off or picked up by a personal vehicle; the driver usually must stay with the vehicle while waiting for the commuter. Both park-and-ride and kiss-and-ride systems are effective at encouraging commuters to take mass transit.

A system that is related to park-and-ride and kiss-and-ride programs is called “bike and ride.” Bike and ride is similar to the others in that it seeks to encourage mixed-mode travel. Bike-and-ride programs provide secure parking or storage for commuters’ bicycles. Because many bicycle riders are reluctant to leave their property unattended and risk vandalism or theft, bike-and-ride programs might provide some sort of monitoring or other security system that will protect the bicycles. Some bike-and-ride systems, especially, but not limited to, those run by bus lines, permit bicycles on the transit vehicle. On buses, the storage is sometimes provided on a rack on the front of the bus; on trains and light rail systems, storage space is usually provided near the doors. Again, bike-and-ride programs are successful when they attract commuters who would otherwise take an automobile and result in reduced congestion and pollution.

Other Mixed-Mode Transit

In large metropolitan areas, extensive railway and bus systems often exist separately. Those cities that seek to encourage mixed-mode transit systems link together their various systems. Doing so enables commuters to reach more destinations than they would by traveling exclusively on the train, light rail, or bus. A specific way of linking the two or more systems is to use feeder buses to direct commuters to train or light-rail systems. Feeder buses run through neighborhoods with a high density of residential units, and pick up commuters who might find it too far to walk to a train or light rail station. To encourage the use of feeder buses, they are scheduled so that they arrive at the train or light rail station shortly before departure times for outgoing trips and shortly after arrival for return trips. This reduces the time commuters must wait and increases their overall satisfaction with the dual-mode process.

To encourage car drivers to use more efficient and environmentally beneficial transit for long-distance journeys, some trains and ferries are constructed with the ability to carry automobiles as well as passengers. While planners and policymakers understand that vacationing families might prefer to have access to an automobile while on holiday, that vehicle does not need to be the only mode used for the journey. Passenger trains that have the capacity to carry automobiles are sometimes referred to as “motorail,” and they are especially attractive to people planning a stay of several months at their final destination. Ferries, which often can save travelers time when compared to driving the entire route, are another effective means to reduce congestion and gridlock while encouraging sustainable practices.

Transit Centers

Transit centers often play a key role in encouraging the use of mixed-mode transit systems. Transit centers assist in reducing congestion, pollution, and gridlock by allowing commuters easy access to two or more modes of transportation in one location. While location ultimately plays the largest role in an individual’s decision whether or not to use mixed-mode transportation, effective planning and policy decisions can assist in improving the attractiveness of the commuter’s ultimate choice. In order to entice users to transit centers, many such locations have found it effective to offer a variety of amenities to travelers utilizing the facility. These include



Jodhpur, India, has well established rail, road, and air networks connecting it to other major cities in the country; however, it is still common to travel by using a camel to pull a cart.

newsstands, coffee shops, bars, restaurants, dry cleaners, flower and gift shops, and other goods and services that are popular in the community being served.

Benefits and Problems

Mixed-mode transit systems combine the advantages of various modes of travel while reducing some of the disadvantages of each. An effective park-and-ride system, for example, permits commuters to travel from their homes to their final destination conveniently while also reducing crowding on the road by providing easy access to a train or light rail. Those who travel by mixed-mode transit systems often enjoy considerable savings by avoiding areas where automobile parking is prohibitively expensive. At the same time, people who must travel by automobile find that the streets are less congested than would otherwise be the case.

Because train, light rail, bus, and ferry systems incur certain fixed costs whether they are full or not—such as fuel, operators, depreciation of the equipment, and the like—mixed-mode transit systems that increase ridership on mass transit help cover more of those costs.

In some regions, however, mixed-mode transit systems prove ineffective. For example, any mixed-mode transit system that relies upon bicycles or walking will be at a disadvantage for large portions of the year in areas with frequent inclement weather.

Additionally, when one mode of a journey experiences failure, such as when a train is late, the other modes can be disrupted to the extent that a commuter is left stranded. Planners and policy makers are well served to work diligently to minimize such disruptions.

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See Also: Airport Transit Connections; Bicycle Facilities; Heavy Rail Transit; Interstate Highway System; Light Rail Transit; Metropolitan Planning Organizations; Park-and-Ride/Kiss-and-Ride Lots; Rail Transit Systems, U.S.; Transit Centers; Transit Corridor Planning.

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Mobile Emissions

Motorized transport creates emissions in the form of gasses, particles, and noise. While many of these arise directly from fuel combustion, emissions are also created through evaporation and abrasion from different vehicle parts. This entry pertains to airborne emissions generated by motorized surface transport modes, that is, roads, rails, and in shipping. It discusses the main emissions from mobile sources and the factors that influence types and levels of emissions. It also touches on the adverse effects of mobile emissions. The text focuses on emissions associated with vehicle operation. Emissions arising from other processes connected to motorized transport are not within the scope of this entry, although they also play an important role in social

and environmental contexts. Examples include gases, particles, and accidental spills connected with the extraction, refinement, and processing of fossil fuels, and particles and noise arising from the creation and maintenance of transport infrastructure.

Types of Vehicle Emissions

The main component of mobile emissions is carbon dioxide (CO_2), the transport sector's main contributor to climate change. Unlike all other mobile emission components, though, CO_2 is not directly toxic to humans or ecosystems. It is thus generally considered separately and is not covered by this article.

The major components of tailpipe emissions that are of local or regional concern are the following:

Carbon monoxide (CO). CO forms through incomplete combustion of carbon-containing fuels. Introduction and enhancement of vehicle emission standards, catalytic converters and better fuel quality have significantly lowered CO emissions in developed countries. CO can be used as a tracer gas for the dispersion of vehicle emissions because it is comparatively inert, that is, it does not chemically interact with other substances in the atmosphere.

Nitrous oxides (NO_x). NO_x consist of nitrogen dioxide (NO_2) and nitric oxide (NO), both by-products of combustion. Nitric oxide is generally quickly oxidized to form NO_2 after it is released into the atmosphere. NO_2 reacts with both oxygen and volatile organic compounds to form ozone.

Particulate matter (PM). PM does not consist of a single chemical substance but is a collection of both solid and liquid aerosols with different chemical and toxicological qualities. The primary components of PM in mobile emissions are a direct result of fuel combustion, including residues from the incomplete burning of carbon compounds. Secondary PM is formed through chemical reactions from engine emissions after their release from the combustion chamber, and contains nitrogen and sulfur compounds. PM is generally classified by particle size rather than composition. PM_{10} describes particles with a diameter of 10 μm and below (1 μm = 1 micrometer = 1 millionth of a meter). $\text{PM}_{2.5}$ denotes all particles equal to or below 2.5 μm in diameter. Thus $\text{PM}_{2.5}$ is a subclass of PM_{10} . The two size classes are often dealt with separately because PM's effect on

human health relates not only to its composition but also to the particles' size. The smaller they are, the farther the particles can penetrate into the human body, and the worse are the health effects associated with them. The combustion of diesel fuel is associated with greater PM emissions than gasoline.

Volatile organic compounds (VOCs). VOCs contribute to ambient air pollution as by-products of combustion. Vehicle fuels typically contain up to several hundred different VOCs, including, for example, benzene and polyaromatic hydrocarbons, many of which are known carcinogens.

Sulfur dioxide (SO_2). SO_2 is formed during combustion of sulfur-containing fuels and is a major contributor to the phenomenon of acid rain. In Europe and North America, fuels used in land-based transport are no longer permitted to contain large amounts of sulfur (current limit for liquid fuels for land transport in the European Union and proposed by the U.S. Environmental Protection Agency for 2017 is 10 parts per million or 0.001 percent), although heavy diesel used in shipping is subject to much less stringent limitations (limit of 3,500 parts per million or 3.5 percent permitted for international shipping by the International Maritime Organization). Most current global SO_2 emissions from transportation are thus attributable to the shipping sector.

Lead (Pb). In the past, lead was added to gasoline as an antiknocking agent to prevent engine damage from irregular combustion and to improve performance. It has been banned as an additive to fuels for road transport in North America and Europe, but can still be found in other fuel types, including fuel for railway locomotives, shipping, and mobile off-road equipment used in farming, construction, forestry, and other industries, as well as in aviation fuel.

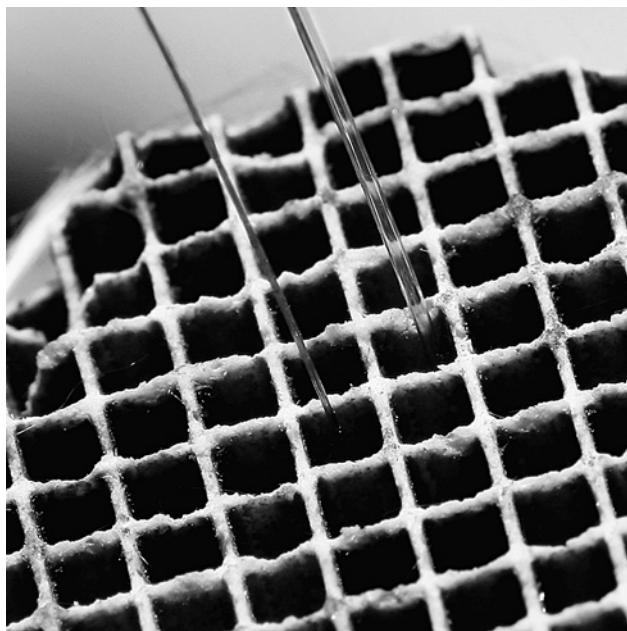
Ozone (O_3). O_3 is not a component of primary mobile emissions, but transportation is the biggest emitter of NO_2 , which, together with ambient oxygen, is the main precursor of this secondary pollutant. Ozone is formed under solar radiation and is one component of so-called photochemical smog.

Smog. Smog is a phenomenon strongly associated with mobile emissions, but the term does not actually describe a particular type of primary or secondary

pollutant. The word is a combination of “smoke” and “fog,” and was in the past mostly associated with smoke from wood and coal burning. Now, photochemical smog associated with solar radiation and reduced convection in the lower atmosphere is more common, at least in Europe and North America.

Other sources. In addition to combustion, there are several other sources of emissions directly associated with the use of motorized vehicles:

- *Evaporative losses.* These are mainly composed of VOCs in gasoline fuel vapors emitted as a result of the following effects: diurnal losses due to temperature changes during the course of a day; running losses due to heat from the running engine; hot soak losses created by heat dissipating from a cooling engine; and cold soak losses from a resting vehicle, as a result of, for example, leaky fuel pipes.
- *Abrasion.* The wear of tires, brakes and clutches (in manual-transmission cars) creates PM that contains heavy metals, among other substances.



Tubes inserted into a catalytic converter allow researchers to sample emissions at the Oak Ridge National Laboratory. Engineers of the 2007 Dodge Ram heavy pickup truck used this test to help the truck meet 2010 emissions control standards three years early.

- *Resuspension.* Air turbulence caused by moving vehicles and the contact of tires with the road surface causes the resuspension of particles that have settled on or near the road. This PM generally contains both primary and secondary particles from mobile emissions, as well as other PM from the ambient air, for example, from stationary fuel combustion in power stations, domestic heating, or biological material such as pollen and fungal spores. The use of off-road mobile equipment in agriculture, forestry, and construction also creates PM from the vehicles, as well as dust from disturbed ground.

Factors Influencing Vehicle Emissions

The composition and amount of emissions generated per vehicle kilometer or mile depend on a number of different factors:

Size and type of vehicle. The vehicle weight and its load (passengers and/or freight), as well as its aerodynamic resistance (shape; loads on decks, trailers or roof racks, etc.), have a major influence on the amount of fuel used and on the emissions created per unit of distance.

Engine characteristics. An engine's technology, age, size, and state of repair influence fuel consumption and the efficiency of combustion. In many countries, legal emission standards for new vehicles have resulted in significantly improved tailpipe emissions over past decades.

In 1992, the European Union, for example, mandated EURO emission standards for new vehicles sold in EU member states. They regulate exhaust emissions of CO, NO_x, VOCs, and PM, and apply to passenger and light-duty vehicles, as well as heavy-duty vehicles and off-road mobile equipment, rail locomotives, and vessels used on inland waterways. The EURO 5 standard in 2013 limits tailpipe emissions of PM to 5mg/km for both diesel and gasoline engines. EURO 4 had no PM standard for gasoline; for diesel engines; the value represents an 80 percent reduction compared to EURO 4.

Electric vehicles create no tailpipe emissions or evaporative losses, but abrasion and re-suspension still occur. The emissions associated with their operation vary depending on the power source

used to generate the electricity they utilize, either directly (for example, electric locomotives and trams) or for charging their batteries (for example, electric cars and trucks).

Catalytic converters oxidize some of the CO and hydrocarbons emitted by gasoline engines to CO₂ and water, while diesel particulate filters remove some of the PM from diesel exhausts. Depending on the technology used, these filters can at the same time increase NO_x emissions, though.

Fuel type and quality. For the same amount of fuel burned, diesel engines create much more particulate matter than do gasoline engines, while the latter emit more VOCs. Fuel standards and quality also play a substantial role in influencing emissions created. One example is the different sulfur content of fuel for land transport versus sea shipping (see above).

Speed and driving conditions. Speed is a strong determinant of fuel use and thus emissions per distance unit. Emissions are normally highest at very low and very high speeds. A steady speed of 50 to 60 miles per hour (80 to 95 kilometers per hour) would theoretically minimize tailpipe emissions from a passenger car. In contrast, a vehicle that achieved a comparable average speed but which alternated between higher and lower speeds would create higher emissions. Similarly, driving styles and driving conditions characterized by alternating bursts of acceleration and deceleration (for example, stop-and-go traffic, abrupt stops and starts at intersections) result in considerably higher emissions. In international shipping, increasing fuel costs have given rise to a practice called slow steaming; ships travel at a lower speed than engine and conditions would allow, resulting in fuel savings and reduced emissions.

Effects of Vehicle Emissions

Local and regional air pollution resulting from mobile emissions can have severe impacts on the health of humans, as well as ecosystems. An association between chronic exposure to such emissions and increased morbidity has been found in both children and adults. Experts generally also agree that there are no levels at which such exposure can be considered safe and that mobile emissions are responsible for significant numbers of premature deaths, especially in urban areas. Primary and secondary mobile emissions, furthermore, contribute to disrupting the

nutrient balance in natural ecosystems and making plants more susceptible to diseases.

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See Also: Air Pollution/Air Quality; Automobile Design; Carbon Monoxide Emissions; Emissions Modeling; Health Issues; Lead Pollution; Low-Emission Vehicles; Nitrogen Oxides; Noise Pollution and Cars; Particulate Matter; Vehicle Emissions Standards; Zero-Emissions Vehicles.

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Mode Choice Models

Mode choice models estimate the share of travelers using each mode of transportation or, in freight transportation, the share by mass, volume, or other related measures. Mode choice models can be aggregate models estimating the percentages of trips used by each mode for a given set of trips or disaggregate models estimating the probabilities of each mode for a specific trip.

Mode choice is one of the most important travel choices an individual makes in terms of sustainable transportation development. If people change behavior to choose more environmentally friendly modes, including public transport, walking, and cycling, rather than private cars, the entire transportation system will become less congested and more sustainable.

Policymakers and transportation planners use mode choice models to a priori evaluate the effectiveness of new transportation infrastructure and services, as well as various transport policies, by estimating mode share shifts in response to new or improved services and policies. Estimating and analyzing such models can help policymakers identify the variables that will encourage shifts to more sustainable modes, including public transportation, cycling, and walking, thus enabling them to better prioritize investments in transportation.

Aggregate and Disaggregate Approaches

Aggregate model choice models take into account many variables about each possible mode of transport the traveler has available for the trip, such as travel time and cost, and estimate the proportion of travelers that would use each mode of transport (for example, 70 percent by car and 30 percent by public transport). This is usually estimated for each origin-destination pair, for a specific period of the day, and for a specific trip purpose.

To better understand travel behavior and the factors that will motivate individuals to shift to more environmentally friendly modes, most mode choice models are disaggregated discrete-choice models. These models have several important advantages over the aggregate approach because they explain why an individual makes a particular choice given her/his circumstances and are, therefore, better able to reflect changes in choice behavior because changes in individual characteristics and attributes of alternatives.

The aggregate approach, in contrast, rests primarily on statistical associations among relevant variables at a level other than that of the individual. The disaggregate approach is more suited for proactive policy analysis because it is causal, less tied to the estimation data, and more likely to include a range of relevant policy variables. Disaggregate discrete-choice models estimate the probabilities that a traveler making a specific trip from zone O to zone D in time period t for purpose p will choose a specific mode m of travel from a given set of available modes c .

In many practical applications, the model is estimated based on disaggregate data (for example, based on individual trips) and then applied in a semiaggregate approach. In this approach, given a trip table of a specific purpose and time of day for each origin–destination, the model will predict the

shares of each mode for each socioeconomic group. Advance travel–demand models move more and more toward agent-based approaches with a full disaggregate application.

In the traditional four-step travel demand modeling, mode choice modeling is the third step following trip generation (How many trips are generated?) and trip distribution (How they are distributed in space?), and preceding trip assignment (Which routes they are using?). When time-of-day modeling precedes mode choice modeling, the latter can account for the level of service for the actual time of day.

Other Model Systems

In more advanced travel-demand model systems, known as activity-based models, travel decisions become part of a broader activity scheduling process based on modeling the demand for activities rather than merely trips. These models estimate the travel choices of each trip segment within the context of all trips taken during a day, or at least within a tour, which is usually defined as a set of subsequent trips starting at home and ending at home. While this complicates the task of mode choice modeling, it also provides more realistic results, because the mode of each trip segment depends on the modes of the other segments of the tour and other attributes of the tour.

Most choice sets include, at a minimum, public transport and automobile. More advanced models include various submodes of public transport, including distinguishing between local bus, express bus, light rail, and heavy rail. Choice sets can also be defined by access and/or egress modes. These usually include park and ride, kiss and ride, bus, and walking. The analysis of transit auto access is very important in the context of analyzing modal shift to public transportation of people with auto availability.

With increasing interest in sustainable transportation, many models also include nonmotorized modes, mostly walking and cycling. The inclusion of all these modes means that the model can easily have a large number of alternatives. Identification of the relevant alternatives (the choice set) depends on the transport system under study, the policy at question and data availability. For example, intracity models will include modes that would not be included in intercity models, such as walk and cycling, while the latter will include modes such as high-speed rail.

In mode choice models, the choice set must be identified for each decision maker, because not

all modes are available for all trips. Modes can be unavailable because of an objective impossibility; for example, driving is not a possibility for a person without a driver's license. They can also be unavailable because they are not perceived as an alternative for a specific trip; for example, heavy rail will not be considered for a trip of a few blocks. When there are a large number of alternatives where some share common attributes, it is common to define nested model structures.

In an example of a nested model structure, at the highest level, the person may choose between private auto and public transportation. In the next level, he or she may choose between driving alone and carpooling if he or she chose private auto, or between bus and rail if he or she chose public transportation. In the last level, the person may choose between various access modes.

Types of Variables

Mode choice models have two main types of explanatory (independent) variables: (1) attributes of the individual and (2) attributes of the alternative travel modes, also considered as policy variables. These two types of variables can also appear in interaction; for example, it is common to include a variable of modal cost divided by income to represent the travel cost relative to one's income.

Attributes of the decision maker are mostly socioeconomic attributes, such as gender, age, income, car availability, and life cycle. Life-cycle variables represent the family stage in life, such as presence and age of children, and working status of the household members. It is common to segment the population to various markets and estimate a model for each market (market segmentation) to account for the different values different markets of the population give to different attributes. Common examples for market segmentation are by auto ownership and income. Another dimension of segmentation is by trip purpose, which represents the different behavior in mode choice decision making for different trip purposes, such as work-related, commuting, shopping, and leisure.

Most attributes of the alternative modes are level-of-service measures describing the level of service they provide to the traveler. These include travel time, travel cost, number of transfers, service reliability, and others. Travel time is usually decomposed into various components—such as

in-vehicle-time, wait time, transfer time, and walking time—because different persons may value each of these differently. Attributes that have negative coefficients usually represent disutility for the traveler. Level of service variables depend on the specific route the traveler will choose to take under each choice of mode. This is done by using the expected utility of the route choice, which, in logit or nested logit models, is the log-sum variable.

Another type of attribute is alternative-specific constants known as modal preferences variables. They account for qualitative characteristics of each mode or for perception differences among modes. For example, a metro may have a higher perceived nonmeasured quality, such as comfort, than a bus.

Value of time (VOT) is derived from mode choice models by calculating the ratio of the marginal utility of time:

$$\left(\frac{\partial U}{\partial t}\right) \text{ (the time coefficient in a linear utility)}$$

$$\text{and the marginal utility of cost } \left(\frac{\partial U}{\partial C}\right)$$

$$\text{(the cost coefficient in a linear utility)}$$

$$VOT = - \frac{\partial U / \partial t}{\partial U / \partial C}$$

This shows the marginal trade-off people are willing to pay in order to save time while keeping their utility at the same level. This value is important input for appraisal purposes to represent the monetary value that people put on their time. Ratios between other coefficients of level of service are also interesting, showing the relative importance of each attribute. For example, the coefficient of out-of-vehicle time is usually two to three times larger in absolute value than the coefficient of in-vehicle time, showing that people are willing to pay more to shorten their wait or walk time than their in-vehicle time. Finally, land-use and urban-form variables of the origin and destination of the trip can be proxies for both level-of-service variables, representing, for example, friendliness of walking, and for the individual, representing, for example, the type of neighborhood in which he or she is residing.

Process

The process of building a mode choice model involves several steps. The first step is model design, in which

the alternatives, model structures, independent variables, and the data to be used are defined. Mode choice models are usually based on the random utility theory. They assume that individuals make decisions that maximize their utility. The utility of an alternative mode is expressed as a function of the various explanatory variables. The most common models structured within this framework are the logit and the nested-logit models, but advances in computing have enabled more flexible model structures to be used, including probit and mixed logit.

The next step is model estimation, where the parameters of the model are determined to best fit the data. This is usually done using the maximum likelihood method. In this method, one tries to estimate the parameters of the model so that the predicted probabilities of the chosen alternative in the estimation data base will be maximized. The last step is model validation, where the model is validated against an independent data set and compared to available aggregate traffic data.

Mode choice models are best estimated using revealed-preference data, where the mode choices made by people are actually observed. These data are usually obtained by travel surveys, which are often conducted by local or national governments using different methodologies. Most common are travel-habit surveys, where respondents are asked to fill a travel diary in which they report on all trips they have taken during a period of time, usually at least 24 hours. For each trip they conducted, survey respondents are asked to report from where to where they traveled, at what time of day, and how long it took them, for what purpose, and by which mode.

However, many mode choice models are designed to evaluate new modes and policies that do not currently exist in a specific area. In such cases, it is common to use stated preference data, where people are faced with hypothetical alternatives and asked to state what would be their choice under various scenarios. These scenarios could include new modes or policies, as well as the level-of-service attributes of the various hypothetical alternatives presented to the respondent. To minimize potential bias with stated-preference data, it is recommended that a combination of revealed- and stated-preference data be used.

There are techniques to best utilize various sources of data and to benefit from the advantage of each type of data. Data on the modal level of service variables can be “skimmed” from the highway and public

transport networks for each origin–destination pair to form matrices. These are called skims because they are obtained from the paths by skimming along the paths accumulating the data. Networks can be skimmed for attributes including in-vehicle time, wait time, walk time, number of transfers, and fare.

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See Also: Activity-Based Models; Freight Transport Models; Level of Service; Mode Share/Mode Choice; Travel Choice; Travel Demand; Urban Transportation Modeling System.

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Mode Share/Mode Choice

The term *mode* refers to the type of transportation used by an individual traveler or the type of transportation used to ship goods or other materials. For example, when individuals travel in an urban area, they might walk, bicycle, use public transit (for example, bus, light rail, commuter rail), use a personal motor vehicle (for example, car, truck, van, motorcycle), or use other modes. Similarly, freight may be shipped by truck, train, airplane, water vessel, or another mode.

Mode Share

Mode share is the portion of movement done by each mode. Mode share can be measured as the proportion of trips (that is, movements between an origin and a destination location), travel distance, travel time, or other measures of travel. Distance measurements tend to produce higher mode shares

for higher speed modes; trip-based measures tend to produce higher mode shares for lower speed modes. Some personal trips and freight shipments are multimodal, or use more than one mode between their origin and destination, for example, walk from origin to a bus stop, ride the bus, walk from a second bus stop to destination. Or a postal worker carries a package from origin to a shipping facility, package is shipped by truck to second shipping facility, postal worker carries package from shipping facility to destination.

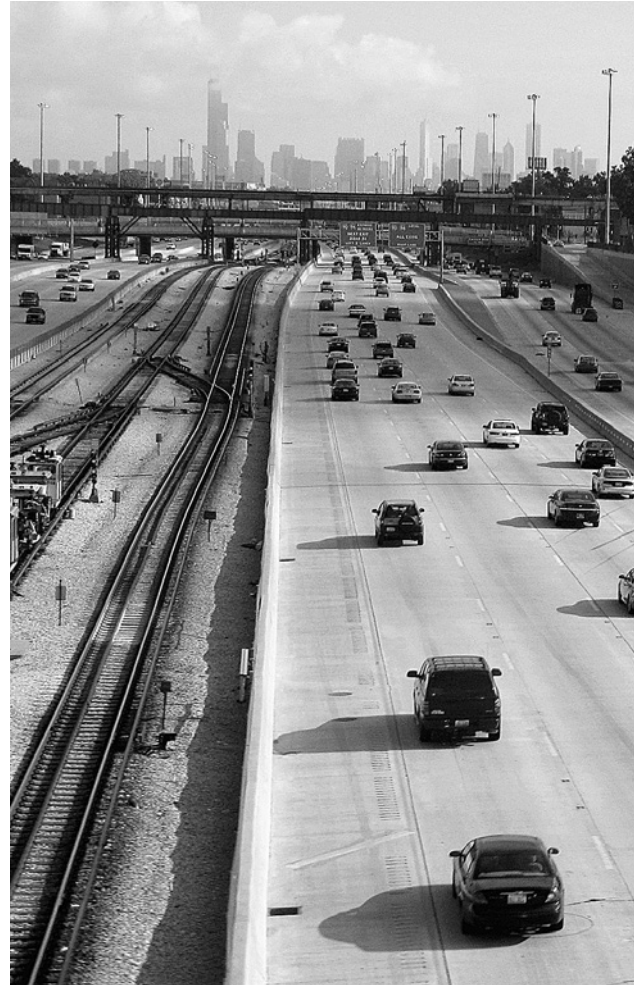
It is common for analysts to consider the mode used for the longest distance between activities to be the primary trip mode. Mode shares can be derived for particular travel purposes (for example, mode share for travel to work or mode share for international exports) or particular travel groups (for example, mode share for low-income households or mode share for coal shipments). Mode shift refers to a change in the proportion of movement done by each mode over time.

According to the U.S. National Household Travel Survey, a private automobile was the primary mode used by individuals for approximately 84 percent of trips between activities in 2008. Other trip mode shares in 2008 included pedestrian (10 percent), public transportation (4 percent), and bicycle (1 percent). The U.S. Freight Analysis Framework, reports trucks were used to ship approximately 68 percent of all freight tonnage in 2011. Other freight shipment mode shares included rail (10 percent), pipeline (8 percent), multiple modes and mail (8 percent), and water (5 percent).

Mode shares vary by geography and time. The Chicago Metropolitan Agency for Planning 2008 Travel Tracker Survey shows that the personal trip mode share across the eight-county region was 80 percent automobile, 10 percent pedestrian, 9 percent public transportation, and 1 percent bicycle. However, the central Chicago trip mode share was 53 percent automobile, 26 percent pedestrian, 17 percent public transportation, and 2 percent bicycle. Considering time of day, the share of public transportation trips is highest during the morning and afternoon; nearly all late-evening trips in the Chicago region are made by automobile.

Mode Choice

Mode choice refers to the selection of a type of transportation to use for a particular purpose.



Cars on the Dan Ryan Expressway heading into Chicago in 2010. Outside of the city's center, personal trip mode share has been estimated at 80 percent automobile, 10 percent pedestrian, 9 percent public transportation, and 1 percent bicycle.

Traditionally, the travel time and cost of using a particular mode have been viewed as the primary drivers of personal and freight transportation mode choice. In recent years, travel behavior researchers have identified other factors that are associated with personal mode choices, including socio-economics (for example, automobile ownership, income, age, gender, and student status), built environment (for example, population and employment density, land-use diversity, roadway characteristics, and neighborhood design), natural environment (for example, weather, topography), attitudes (for example, personal enjoyment of particular modes, cultural influence/social pressure), and perceptions (for example, traffic safety, personal security).

Mode choices are typically analyzed using utility theory. Utility theory is the basis for discrete-choice analysis, which assumes that individuals or firms will choose the mode that is the most attractive among all available alternatives, based on relevant variables (for example, time, cost, comfort) and subject to random error that is not expressed by the variables considered. The family of discrete-choice models includes binary logit, multinomial logit, nested logit, and others. These models can be used to identify variables that are associated with individuals and firms choosing particular modes. They can also be used for forecasting future mode shares in order to predict the impact of transportation investments or other policy changes in a community.

Mode-choice analysis is often simplified to consider only those travel options that are currently available to individuals and firms. However, medium- and long-term decisions also influence mode choices. Individuals purchase or give up vehicles, change jobs, change family structure, and change home locations. Similarly, firms select locations, choose clients and markets, and purchase vehicle fleets, all of which change the relative attractiveness of different transportation options. To varying degrees, people and businesses make these longer-term decisions with future mode choices in mind.

Given the complexity of mode choices, transportation researchers and psychologists have also proposed frameworks to describe mode choice as a decision process. These frameworks include the theory of planned behavior, theory of interpersonal behavior, transtheoretical model, model of normative decision making, and comprehensive action determination model. Rather than treat the selection of a mode as a discrete choice, these theories suggest that mode choices may be subject to social norms, individual preferences, and the development of habits over time.

The operational theory of routine mode choice decisions integrates components of many of these frameworks. This theory describes how people choose transportation modes for routine travel purposes, such as local shopping or other errands. It suggests five steps in the choice process: First, “awareness and availability” determines which modes are viewed as possible choices for routine travel. The next three steps are “basic safety and

security,” “convenience and cost,” and “enjoyment.” These steps assess situational tradeoffs between modes in the choice set, and might be considered simultaneously or in sequence. The final step, “habit,” reinforces previous choices. Socioeconomic characteristics explain differences in how individuals view each step in the process.

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See Also: Mode Choice Models; Traffic Psychology; Travel by Mode; Travel Choice; Trip Chaining.

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Monorails

Monorails have proven efficiency and safety records, but they still face public perception or image problems. Some people think that monorails haven't proven their efficiency as a mass transit method because they are concerned about the practicality and safety of evacuating stranded passengers from overhead trains, and they believe that elevated monorails spoil urban landscapes. The Monorail Society and other monorail proponents counter that monorails are efficient, safe, cost effective, and environmentally friendly. The future expansion of monorail systems depends on overcoming public and taxpayer misconceptions about their cost and effectiveness as a mass transit system.

The Singular Monorail

A railroad transportation system based on a single rail acting as its sole support and guide way, a monorail system is often but not exclusively elevated and can be both manned and unmanned. Several designs of monorails are divided into straddle beam and suspended monorails. The straddle beam monorail, which has a train straddling a steel or reinforced concrete beam within the range of 2 to 3 feet wide, is the most common type of monorail. A carriage with rubber tires connects the beam on the top and both sides for traction and stability. The German company ALWEG popularized the straddle beam. A suspended monorail features a train with cars suspended beneath the wheel carriage with the carriage wheels riding inside the single beam. The French company SAFEGE offers a suspended monorail system. In the 1880s, German inventors Nicolaus Otto and Eugen Langen developed the suspended monorail which opened in the twin cities of Barmen and Elberfeld in the Wupper Valley in 1901, and it is still operating.

Monorail cars can come in a singular rigid format, articulated single units, or as multiple units linked into trains with cars that are wider than the guiderails that support them. Monorails are powered by linear induction motors and their cars are connected to the beam by bogies, which are wheeled wagon or trolley systems that allow the cars to safely negotiate curves. In contrast to some tram and light rail systems, modern monorails are separate from other traffic and pedestrians and, unlike other guided railroad systems, they are

guided and supported with the same single beam. They also do not use a pantograph, a single overhead wire on the roof with return current running through the track.

Monorail Systems

Metropolitan monorail systems are in operation in 178 cities around the world, with 20 in Asia. Ten monorail systems are located in Japan with the longest operational monorail line in the world, a 15-mile corridor in Osaka. The Chinese government is constructing a crisscrossing network of monorail corridors to expand the 28-mile Chennai, China monorail system that it estimates will be 186 miles long if it is completed according to plan.

Monorail systems have been operating since the 19th century, but in their pioneering years they were primarily short line systems that moved small amounts of freight and passengers. On June 25, 1825, the Cheshunt Railway in Cheshunt, England celebrated its grand opening, earning its place in history as the first passenger-carrying monorail. In 1876, the Sonoma Prismoidal, a 7-mile wooden monorail, was planned to be the first rail line built to connect Sonoma in northern California with a steam ship landing at the San Pablo Bay. Only 3.5 miles of the line with a 15-inch-high track were built between Norfolk and Sonoma, at a cost of \$4,500 per mile, half of the cost of contemporary narrow gauge railroads. Although the railroad operated from November 23, 1876, to May 5, 1877, promoter Joseph S. Kohn never realized his plans to extend the monorail to Sonoma Landing on the Petaluma River or build an elevated prismoidal rail along Market Street in San Francisco.

The oil boom of the 1870s in Pennsylvania produced a modified version of the monorail line running between Bradford and Gilmore. In 1878, oil company backers built the monorail to transport oil drilling equipment and people to Derrick City, with wayside stations added at Tarpot, Babcock's Mill and Harrisburg Run. Since the rotary engines lacked power, the builders decided to use a larger locomotive driven by local pistons. On January 27, 1879, as the train ran at high speed to demonstrate its effectiveness to company officials and onlookers, the boiler exploded and it crashed into a creek, killing the driver, fireman, and three passengers and severely injuring several others. The oil company abandoned the line shortly after the accident.

In 1886, the Enos Electric Railway tested and demonstrated the first suspended monorail at the Daft Electric Company in Greenville, New Jersey. The newspapers gave the Greenville demonstration considerable publicity, but Enos Electric Railway didn't build a major monorail system. The monorail itself featured a light, open steelwork design instead of the traditional massive wooden beams, a design that may have influenced civil engineer Eugen Langen of Cologne, Germany, since the Enos Monorail closely resembles the Wuppertal Schwebebahn in Germany. In fact, Langen deserves widespread recognition for his Schwebebahn, or suspension railway, which has operated successfully and profitably along the Wupper River since 1901.

Frenchman Charles Lartigue designed the original steam-powered monorail which ran for 9 miles between Listowel and Ballybunion, Ireland, from 1888 to 1924. The only monorail of its kind to enjoy commercial success, it carried passengers, livestock, and freight along a rail supported on A-shaped trestles, and during its lifetime it provided curiosity and amusement.

Monorail technology continued to advance and improve in the 20th and 21st centuries. Inventor Louis Brennan patented his monorail car balanced with gyroscopes in 1903, and on November 10, 1909, he demonstrated to the press that even with passengers grouped on one side of the car, the two onboard gyroscopes were strong enough to keep the car level. Despite successfully demonstrating his car several times to scientists, engineers, and military officers, Brennan never had the satisfaction of seeing his monorail used for transportation, because investors and officials feared that the gyroscopes might fail.

In 1910, William H. Boyes and two assistants, whose names have been lost to history founded the Seattle–Tacoma Monorail Company to provide high-speed rail service between Puget Sound cities in Washington State. He built a test track with wooden rails in 1911 at the estimated cost of around \$3,000 per mile, but he couldn't develop it further because of the lack of financial backing.

In 1924, the Sierra Salt Corporation built one of the last Lartigue-style monorails to carry magnesium salts from the mine in Crystal Hills across the rugged terrain of the Saline Valley to the Trona railroad in California. The monorail line worked

successfully until modern technology made extracting magnesium easy and the mining company went out of business in 1926.

In 1947, a French consortium of 25 companies including Michelin and Renault, and a design team headed by Lucien Chadenson produced a new monorail technology. Impressed by the Paris Metro Route 11 and the Bennie Railplane experimental line operating near Glasgow, Scotland, designer Chadenson decided to combine the two ideas and he produced a suspended monorail with bogies protected from the weather inside a steel or concrete box beam above the train. Calling his design the Safege Monorail, Chadenson operated the test track south of Paris for many years. The Siemens Company in Germany developed a smaller system similar to the Safege Monorail and Aerorail of Dallas, Texas, and Sky Train of Palm Harbor, Florida, also operate steel wheel versions of Safege.

By the 1950s Alweg monorails, including the the systems in Germany and at Disneyland and Disney World, had captured the attention of a segment of the public. In 1952, Swedish industrialist Dr. Axel Lennart Wenner-Gren built the first monorail test track in Germany after World War II and tested it on the Fuhlingen track with a system design geared toward a high-speed, city-to-city rail system. Although the Alweg system impressed people with its stellar speed and banking capabilities, it did not settle into its niche until 1957, when Alweg unveiled and tested its first modified full-scale monorail at the Fuhlingen track. The successful test caught the attention of a Walt Disney representative, and in 1959, Disneyland opened its Alweg monorail. As technology progressed, so did versions of the Disneyland Alweg monorail, and in 1971, Walt Disney World in Florida built a large dual-rail system, which on a typical day carries more than 150,000 visitors around the resort and theme park.

While many Americans thought of monorails simply as theme park rides, Japan included the monorail in its extensive campaign to improve its transportation system. In 1957, the first Japanese monorail system appeared at the Ueno Zoo in Tokyo, when the Ueno line replicated Wuppertal's system using unique parts, including rubber tires. Japan adopted the Alweg and Safege monorail systems and eventually built more transit monorails than any other country in the world, including a

full-sized Alweg monorail for the Tokyo Disneyland Resort in the 1990s.

Monorail systems also cornered a portion of the 1960s transportation market, including the 1962 Seattle World's Fair, with a dual-rail Alweg line which still operates today. To promote their Safege licensed monorail, the American Machine and Foundry Company (AMF) installed and operated a one-station I-Beam monorail with dual-rail systems looping around the amusement area for the 1964–65 New York World's Fair. Although AMF never sold or built any Safege monorails, the system they installed at the New York World's Fair drew more enthusiastic attention to monorail systems.

In 1964, the Tokyo–Haneda Monorail, the first major system to incorporate the Alweg design and use switches for direction reversal, opened, and it continues to operate safely and profitably into the 21st century. Since the mid 1950s, Japan has used monorails to carry commuters in large cities like Tokyo and Osaka, and Osaka has the longest monorail line in the world. Osaka's 17-mile-long monorail connects the airport to 17 other stations.

São Paulo

Although São Paulo, Brazil, is the largest city in South America with more than 11 million residents, it has only about 44 miles of subway lines that carry an average of 3.6 million passengers a day. City officials are expanding several transportation modes, but they are focusing especially on monorails as the cheapest and fastest way to relieve transportation congestion. Line 17-Gold is a planned 11-mile monorail system that will connect Congonhas International Airport to the metro rail network in São Paulo, beginning at Jabaquara terminus station on Line 1-Blue and ending at Morumbi station of Line 4-yellow and passing through the southern and southwestern part of the city. The arch-shaped route will link four metro lines and three bus corridors and feature 18 stations.

Companhia do Metropolitano de São Paulo (CMSP), the line operator, contracted with a consortium made up of Scomi Engineering of Malaysia, Andrade Gutierrez, CR Almeida, Engenharia de obras and Montagens e Projectos Especiais for the \$862-million project in June 2011 to build the monorail system, which is expected to take three and one-half years to complete, with a completion date set for 2016. One of the three monorail lines



The Sydney, Australia, straddle-beam monorail, shown here in 2012, operated from 1988 to 2013. It ran in only a single 2.2-mile loop and suffered from low ridership.

being planned for São Paulo, Line 17, is expected to serve 252,000 passengers a day with trains traveling at a headway of 200 seconds.

According to the terms of the contract, Malaysia-based Scomi Engineering will furnish the rolling stock, the vehicle management systems, switch design and system integration, assurance testing and commissioning. Scomi Engineering will supply 24 car train sets of its Sutra monorail trains, which have the capacity to transport 400 passengers in each direction. Sutra Monorail features a straddle-type car with a single-shell body made of composite materials. Each cab has six windows and four bi-parting, external sliding doors; the cab interior is spacious and allows passengers to move around freely. The car is equipped with a 40-kilowatt, roof-mounted air-conditioned unit

and it moves on a single beam on an elevated corridor, occupying minimal space. The Sutra Monorail uses an electric motor, runs on a lower power supply, and is designed to travel at a top speed of approximately 56 miles an hour. The Sutra is designed with the capability of installing an automatic train protection system and automatic train operation equipment; its vehicle management system provides system supervisory, control, monitoring, and diagnostic functions.

Metro São Paulo plans to complete three other monorail systems by 2015. Line 2-Green extension opened in 2012 with 17 stations. Line 16-Silver is expected to be 5 miles long with 10 stations. Work on Silver began in 2012 and is scheduled to be finished by 2015. Canadian train and plane maker Bombardier, Inc., was one of a consortium of companies winning a contract worth \$1.44 billion to build the first new 14.9-mile section. The monorail, with 17 stations and 54 seven-car trains, will connect several low-income neighborhoods to existing subway service. Planners estimate that the monorail line, scheduled to open in 2014, will draw approximately 40,000 commuters per hour from all directions.

Costs of Building a Monorail System

According to the Monorail Society, an organization that gathers data and promotes use of monorail technology, the most popular question that people ask about monorail is how much they cost to build; according to the Monorail Society, there is no simple answer to the question. The costs of monorail systems range from the \$120 million infrastructure and operating costs of the Osaka, Japan, monorail system opened in 1990 to the \$1.44 billion contract that Bombardier, Inc., signed to build a monorail system in São Paulo, which is scheduled to open in 2014.

A variety of variables and circumstances influence the price of building a monorail system. The total length of the system is important, and a general rule of thumb can be the longer the system is, the lower the cost. Topography or the lay of the land is an important cost factor as is whether the land is flat or hilly. The number of roads and rivers to cross and the amount of land needing to be purchased or easements secured are also important. The location and access to the land and relocating or locating utilities also affect the cost of building

a monorail. Factors like access for construction equipment, and traffic and other impediments to construction, as well as relocating water mains, and power and telephone lines, influence monorail costs. The size and number of passenger vehicles and the number of stations required, as well as special structures like tunnels, bridges, overpasses and urban structures, add to the cost of monorail construction. Environmental mitigation such as the restoration and protection of wildlife is also a cost factor.

The Monorail Association contends that despite the cost of building it, a monorail system has one of the best chances of all transit modes of turning a profit, and it publishes an alphabetical list of the approximate costs figures of various monorail systems on its Web site. The Monorail Association also advises that the list is in no way complete and readers can obtain more accurate cost figures from the manufacturer or a monorail savvy consultant.

Advantages and Disadvantages

Historically, monorails have had mixed reviews, with one faction hailing them as a model for future public transportation systems and critics relegating them to theme park attractions too slow and small to serve as urban transit systems.

Now large cities in emerging economies looking for quick, low-cost solutions to mobility bottlenecks are scrutinizing the advantages of elevated single-track trains. Besides Chongqing, China, and São Paulo, Brazil, monorail systems are being constructed in Mumbai, India; Riyadh, Saudi Arabia; Daegu, South Korea; and at least a dozen other places around the world.

Despite successful monorail construction, Kim Pedersen, head of the Monorail Society in 2013, believes that the perception that monorail is unproven in a mass transit setting has persisted. Concerns about evacuating stranded passengers from overhead trains and the idea that elevated monorails spoil urban landscapes have also hindered the growth of monorails.

Monorail makers like Bombardier and Hitachi Ltd. state that modern monorails are quieter and vibrate less than earlier models. Some of the new trains are lighter, which means that elevated structures aren't as bulky and allow more natural light than do older designs. Bombardier also reports that the São Paulo system will feature evacuation walks between tracks,

and Eran Gartner, president of the transportation division of Bombardier in 2013, which also builds other train systems, says subways can cost roughly 50 percent more than monorails to build depending on their location.

Opponents of monorail systems argue that most people won't forsake their cars to ride monorail systems, but some people will decide to take the monorail instead of driving for at least a few of their trips, especially those that involve driving in congested traffic and costly downtown parking. Other monorail opponents argue that monorail systems costs too much, but light rail or subway costs much more, while bus rapid transit costs less but is slower and has more impact on traffic. Critics question whether monorail systems can ever be suitable for urban mass transit. In 2013, George Haikais headed the Institute for Rational Urban Mobility, a New York-based nonprofit organization focused on transportation reform. He believed that the efficiency of monorail was still an open-ended question and "the evidence is that it is not a substitute for conventional railroad at least when it comes to carrying large numbers of passengers."

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See Also: Airport Planning; Airport Transit Connections; Automated Guideway Transit; High Speed Rail, Design and Technology of; Rail Transit Planning, U.S.; Rail Transit Planning, Worldwide; Railroad Automation Technology; Transit Corridor Planning; Transit Planning, International.

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Motor Carrier Act of 1980

Trucking companies account for more than half of the shipping value and tonnage transported throughout the United States each year, making the motor carriage a leading mode of freight transportation across the country. The industry became federally regulated under the Motor Carrier Act of 1935 and remained subject to government-imposed restrictions until the Motor Carrier Act of 1980 eased controls and ushered in the prevailing era of deregulation.

In the deregulated environment, motor carrier companies have become more innovative and efficient in their operations and more focused on delivering service quality at a reasonable cost in order to succeed in the increasingly competitive market.

Historical Perspective

Motor carriers in the United States enjoyed broad independence prior to 1935. The freedoms led to a glut of providers and generated an oversupply of transportation services that stifled pricing and profits. In efforts to remain competitive in the years during and following the Great Depression, many trucking operators resorted to dangerous and sometimes unscrupulous activities, ranging from foregoing equipment maintenance and requiring drivers to work extended hours to abandoning shipments midway through a job and even racketeering.

Congress stepped in to provide regulatory structure with the Motor Carrier Act of 1935. The legislation gave the Interstate Commerce Commission authority to issue and enforce regulations designed to protect industry participants and the shipping public from corrupt practices. The regulatory system succeeded in reducing bad behaviors, but it also gave rise to such stringent entry requirements that near-monopolies were created and prices for motor carriage soared.

The Motor Carrier Act of 1935 required truckers to have a certificate of public convenience and necessity before they could operate as a motor carrier. Obtaining the required certificate was extremely difficult, because it placed a heavy burden of proof on the trucker. For example, established truckers had to submit extensive documentation demonstrating that they operated as a motor carrier prior to 1935. New companies seeking to enter the industry were required to establish, among

other things, that their service was consistent with the public interest and did not unnecessarily duplicate established motor carrier services. In addition, the Interstate Commerce Commission determined that existing motor carriers should be given authority over new ones, making it hard to expand or create new services. Regulatory restrictions on driving through other truckers' routes muddled things further, because some carriers were forced to choose alternate routes that added hundreds of miles to the journey just to avoid another trucker's route.

Motor carriers were required under the 1935 act to file their rates with the Interstate Commerce Commission 30 days prior to the intended effective date. Once filed, competitors were permitted to review each other's rates and contest them. Moreover, regulatory price controls prevented carriers from raising rates, leading them to pass tariffs and other cost-of-business increases directly onto customers. Under the administration of President Jimmy Carter, Congress passed the Motor Carrier Act of 1980 in an effort to strike a better balance within the industry and get pricing under control. While it did not completely deregulate the motor carrier industry, the act did ease barriers to entry and price restrictions. The increased flexibility was intended to have an anti-inflationary effect on the costs of doing business, both within the motor carriage industry and for companies and consumers using freight trucking services.

Specifically, the act was designed to promote fair competition and reasonable rates for the movement of goods via motor carriers, facilitate diversity in quality and price options to meet market demands and consumer requirements, and enable motor carrier operators to earn sufficient profits, lure capital, and maintain fair wages and working conditions.

Impact of Deregulation

The Motor Carrier Act of 1980 changed the regulatory procedures for obtaining trucking licenses, utilizing routes, publishing rates, and setting prices. The less restrictive operating environment led to an increase in competition, with the number of trucking companies in the United States increasing dramatically following implementation of the act. In particular, there was a significant increase in the number of small-truckload operators, most of whom could not have gotten operating certificates required under the earlier regulation because of

the process and costs involved. Following the 1980 act, these smaller carriers were able to obtain their own operating certificates, enabling them to offer services as independent providers within interstate markets. The number of licensed motor carriers more than doubled from approximately 18,000 to around 45,000 in the first decade after deregulation.

Another form of entry in the postderegulation motor carrier industry was from previously certified carriers that had been restricted by route-use rules. After 1980, they were able to enter new geographic regions more easily. Truckers could also avoid costly and lengthy detours, and expand, specialize, and better coordinate their networks to achieve economies of scale and scope. The new environment also enabled carriers to lower operating costs. For example, labor and time expenses, as well as fuel costs that used to be required to accommodate shipments via circuitous routes, were suddenly available for other uses.

With increased flexibility in both pricing and service arrangements provided under the Motor Carrier Act, U.S. motor carriers were able to respond more fluidly and naturally to evolving market conditions. Among the favorable consequences were generalized price reductions and increased efficiencies tied to inventories, movement of goods, and service levels. On the negative side, trucking workers overall were paid less in salary and wages after deregulation. In the regulated environment, a majority of truckers belonged to workers' unions that ensured they were paid some 50 percent more than workers in comparable occupations. After 1980, the number of unionized workers dropped significantly percentagewise as more independent and low-cost smaller operators without union representation took advantage of the less restrictive entry requirements and joined the playing field.

The increase in number and breadth of motor carrier providers served to substantially heighten competition throughout the industry. Diminished regulatory requirements and removal of antitrust issues prompted many carriers for the first time to look beyond price as the main differentiating factor. In large part, motor carriers across the United States expanded to include technology advances, more innovative tactics, and customized collaborations in order to remain profitable and competitive. The focus turned toward selling service quality in the form of swift service completion, reliable service

guarantees, appropriate equipment availability, and improved information technology capabilities.

Related Legislation

Since the passage of the Motor Carrier Act of 1980, other acts of legislation pertaining to trucking transport have been passed to address issues such as rate protection and transportation safety.

The Negotiated Rates Act of 1993 offered shippers options and protections regarding undercharge agreements on interstate shipments. An undercharge occurs when a carrier agrees in good faith to a discounted shipping rate. The act also prohibited off-invoice discounting in which suppliers would obtain a discounted transportation rate from their carriers while the receiver would be billed for the full rate.

The Trucking Industry Regulatory Reform Act of 1994 eliminated the need to file individually determined rates with the Interstate Commerce Commission, and established a 180-day limitation for contesting freight invoices. The following year, however, the Interstate Commerce Commission Termination Act of 1995 abolished the commission and transferred some of its authorities, such as licensing and economic regulation, to the Federal Highway Administration and the Surface Transportation Board. Following the passing of the Motor Carrier Safety Improvement Act of 1999, the Federal Motor Carrier Safety Administration was established as of January 1, 2000. The agency currently holds primary regulatory responsibility for the operations of motor carrier brokers and freight forwarders.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) of 2005 reduced the licensing and bonding requirements for third-party surface transportation brokers and freight forwarders.

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See Also: Deregulation; Federal Highway Administration; Federal Motor Carrier Safety Administration; Federal Transportation Policy; Freight Rates/Tariffs; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Surface Transportation Board; Transportation, Economics of; Trucking Industry, Economics of; Trucks, Safety Issues and.

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Motor Fuel Taxes

A major component of road and highway funding in the United States comes from motor fuel tax revenues. Motor fuel taxes are the largest source of highway revenues at the federal level and have been one of the primary approaches used by the states to finance their highways and roads. Motor fuel taxes are levied as a fixed amount per gallon. Since the mid-1990s, the federal gasoline tax has been set at 18.4 cents per gallon (cpg) and the federal diesel tax at 24.4 cpg; these taxes make up the bulk of federal funds in the Highway Trust Fund. However, there are several challenges associated with the fuel tax in its current structure, and alternatives, such as the vehicle miles traveled (VMT) fee and a tax based on equivalent standard axle loads (ESAL), are being considered by policymakers and researchers.

Economic Principles

The theory behind the motor fuel tax is that the people and businesses using the roads should pay for their construction and upkeep through an equation that relates to their usage. This would, for example, account for things such as the number of miles traveled, the wear imposed by the vehicle (which is highly correlated to vehicle weight), additional congestion caused by the vehicle's operation, and pollution emitted by the vehicle. Implementing a user fee system would also directly correlate to all these factors, but it would be quite costly and could have significant potential drawbacks. An alternative to this direct charge is to tax a complementary good—in this case, gasoline.

Fuel consumption is related to road use in two important ways. First, the more a person drives, the

more gasoline is consumed. As a result, more tax revenue is paid by individuals who travel greater distances or rely more heavily on roads for transportation. Second, heavier vehicles tend to use more gasoline per mile of travel than lighter vehicles. Heavier vehicles, which impose more of a physical burden on the existing roads, will then pay more in taxes compared to lighter vehicles.

Historically, the gas tax has been considered somewhat equitable. More recently, the widening variation in vehicle fuel efficiency and the development of alternative fuels have broken the clear link between fuel usage and the costs a given vehicle would impose on the road system, thus weakening the assumed equity of the motor fuel tax.

There have been concerns that lower income groups might bear a disproportionate burden of gasoline cost and its associated taxes. However, research in the United States has found mixed evidence that the fuel tax is regressive. In addition, fuel taxes could account for the environmental costs attributed to various vehicle users and, by discouraging fuel purchases and driving, help reduce air pollution, carbon dioxide emissions, traffic congestion, traffic accidents, and oil dependency.

Motor Fuel Tax Structure and Rates

In the United States, the states took the lead in introducing and implementing the motor fuel tax. Oregon was the first state to introduce the motor fuel tax in 1919, and within 10 years, every state had followed suit and enacted its own fuel tax. At the federal level, the fuel tax was first levied in 1932. Each state, as well as the federal government, sets its own tax rates for different fuels (for example, gasoline, diesel, gasohol, and other special fuels). The motor fuel tax is a manufacturer's excise tax; therefore, the first entity to refine, distribute, or wholesale gasoline (and other motor fuels) pays the tax on the fuel. Often, this tax-paying entity is a distributor, importer, refiner, retail manufacturer, licensed dealer, supplier, or wholesale distributor, who then incorporates the tax into the wholesale price and passes it through to the end user.

The traditional fuel tax is structured as a fixed-rate tax, where the tax rate is statutorily defined and can only be changed by an act of legislation. For most states with traditional motor-fuel-tax rate structures, the tax rate remains fixed at X cents per gallon until legislation is passed changing

the tax rate to Y cents per gallon. The frequency of legislation, along with the size of the changes to the tax rates, dictates how well the motor fuel tax responds to changes such as increasing fuel efficiency or inflation. It is often politically difficult for legislators to raise the tax rate. As such, rate changes are often far and few between.

Most states and the federal government have the traditional fixed-rate structure. Several states, however, have a variable or indexed tax-rate structure where the tax rate adjusts automatically with changing rates of inflation or changing fuel economy. Since 1970, 16 states and the District of Columbia have employed some form of the variable-rate fuel tax structure. As of 2010, seven states had variable-rate fuel taxes.

When the federal gasoline tax was introduced in 1932, the tax rate was 1 cpg. As shown in Table 1, the federal tax rate has been continuously authorized but at levels that have varied across the years. Currently, the federal tax rate on gasoline is 18.4 cpg and the federal tax rate on diesel is 24.4 cpg.

Table 1 Federal tax on gasoline

Tax Rate (cents per gallon)	Applicable Period
1.0	June 21, 1932 to June 16, 1933
1.5	June 17, 1933 to December 31, 1933
1.0	January 1, 1934 to June 30, 1940
1.5	July 1, 1940 to October 31, 1951
2.0	November 1, 1951 to June 30, 1956
3.0	July 1, 1956 to September 30, 1959
4.0	October 1, 1959 to March 31, 1983
9.0	April 1, 1983 to December 31, 1986
9.1	January 1, 1987 to August 31, 1990
9.0	September 1, 1990 to November 30, 1990
14.1	December 1, 1990 to September 30, 1993
18.4	October 1, 1993 to December 31, 1995
18.3	January 1, 1996 to September 30, 1997
18.4	October 1, 1997 to September 30, 2016

Source: Bickley, James M. "The Federal Excise Tax on Gasoline and the Highway Trust Fund: A Short History." Congressional Research Service (September 7, 2012).

Significant variations in tax rates can also be seen across the states. For example, while the average tax rate is approximately 21 cpg, the tax rates for gasoline and diesel are the lowest in Georgia (7.5 cpg for each) and highest in Washington (gasoline tax rate of 37.5 cpg) and Connecticut (diesel tax rate of 46.2 cpg).

Even when the federal and state taxes are combined, the fuel tax in the United States is the lowest among industrial countries. In fact, gasoline and diesel are more heavily taxed in other developed, emerging, and developing countries. The combined tax of approximately 40 cpg (federal 18.4 cpg combined with state average of 21.4 cpg) in the United States is only a fraction of the United Kingdom's gasoline tax of approximately \$2.89 per gallon.

According to data from the Organisation for Economic Co-operation and Development (OECD), the United States has the lowest fuel tax compared to other member countries of the International Energy Agency (IEA). The U.S. tax on unleaded gasoline comprised only 16.5 percent of the unleaded gasoline price paid by consumers in 2010. In comparison, the Netherlands and United Kingdom had the highest fuel tax as a percentage of the unleaded gasoline price (63.4 percent and 62.3 percent, respectively). Canada's fuel tax component was 32.2 percent and Australia's was 37.2 percent. As shown in Table 2, in December 2012, the United States had the lowest average end-use tax on gasoline and

diesel compared to France, Germany, Italy, Spain, United Kingdom, Japan, and Canada.

Challenges and Alternatives to the Fuel Tax

Over the past 50 years, the ability of fuel tax revenues to finance transportation has declined. This is the result of two factors. First, inflation has diminished the purchasing power of the fuel tax, because, absent statutory changes to the tax rate, the traditional fixed per-gallon fuel tax does not respond to inflationary pressures. While the nominal gas tax has continued to increase, the real tax rates have declined.

Second, improvements in vehicle fuel efficiency have resulted in less gasoline consumption per mile driven, which decreases fuel tax revenue even though the actual cost drivers impose on the roads through their usage is not decreased by the increased fuel efficiency. Because of this, users are paying less per mile driven today than they were years ago, assuming a constant real gas-tax rate. Improvements in vehicle fuel efficiency, coupled with the real decline in tax rates, has led to concerns over the continued viability and sustainability of fuel taxes as a source of transportation funding.

A simple solution to the fuel-tax problem could be to replace the traditional, fixed-rate structure with a variable-rate or indexed tax instead. The primary advantage of this variable structure is that it automates adjustments to the tax rate to maintain long-term real revenue, while at the same time avoiding the political battles and uncertainty that accompany tax legislation. The variable-rate structure, if indexed to inflation and fuel efficiency, would address the two key challenges of inflation and improving fuel efficiency. However, another major problem with the fuel tax is that it does not tax the distance travelled. An alternative to the fuel tax would be a user charge based on the distance traveled, instead of on the fuel consumed to travel the distance. Several states have experimented with fees based on the amount of travel undertaken, the time of day the road usage occurs, the type of vehicle, and the type of road being used. This fee, called the vehicle-miles traveled (VMT) fee, is a much better approximation of a user fee than the current fuel tax. However, a fixed VMT fee structure that is not indexed to some measure of inflation would suffer the same fate as the traditional fixed-rate motor-fuel tax when it comes to maintaining purchasing power.

Table 2 Average end-use tax per gallon of fuel (in \$ equivalents), as of December 2012

IEA Country	Gasoline	Diesel
France	4.139	2.067
Germany	4.512	2.335
Italy	5.093	3.041
Spain	3.449	1.824
United Kingdom	4.894	3.544
Japan	2.839	1.745
Canada	1.507	1.190
United States	0.420	0.485

Source: International Energy Agency. "End-Use Petroleum Product Prices and Average Crude Oil Import Costs, December 2012." <http://www.iea.org/stats/surveys/Prices/2012/MEMDEC12.XLS> (Accessed May 2013).

Another distance-based alternative would involve taxing trucks in proportion to the damage they inflict on roads. Pavement damage is a function of vehicle weight per axle, and can be defined in terms of equivalent standard axle loads (ESAL) causing the same damage. An ESAL-miles tax or fee would be proportional to the damage caused and the maintenance needed to fix the damage. An ESAL-miles tax or fee would have the added advantage of shifting some freight shipments to rail and barge, and reducing the need for new highway construction on some congested routes. It would also incentivize use of trucks with lower loads per axle or trucks with more axles, decreasing the damage to highways.

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See Also: Highway Finance; Highway Trust Fund; Vehicle Miles Taxation/Fees.

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are less expensive to purchase, require less fuel, are easier to maneuver in congested traffic, and more convenient to park, they have become the staple motor vehicle in many developing countries in southern and eastern Asia. The four largest motorcycle markets in the world are China, India, Indonesia, and Vietnam. In the United States, there are approximately 11 million motorcycles, and the estimated number of Americans who ride motorcycles at least once a year is 25 million.

Motorcycles are primarily used as leisure vehicles by the American population; roughly 80 percent of the miles put on a motorcycle are from recreational trips, and 20 percent for commuting. Motorcycle registrations in the United States are increasing as people choose them to reduce gasoline consumption and urban congestion. While only 9 percent of the total U.S. adult population owns a motorcycle, they are 35 times more likely to experience a fatal accident on the road than automobile drivers. Head injuries are the leading cause of death in motorcycle crashes.

In spite of increasing motorcycle ownership in the United States, motorcycle riders are perceived in popular consciousness as rebels, criminals, and outsiders. From state to state, there is also a wide variety of definitions for categories of motorcycle. For these reasons, not all states require a distinct type of license or test for each variety of motorcycle. Some types of motorcycle are not subject to the same insurance or registration requirements as other motor vehicles. Along with the increasing rate of motorcycle accidents in the United States, these factors have led some people to call for a ban on some or all types of motorcycles. Meanwhile, motorcycle enthusiasts are lobbying the motorcycle producers for more safety features, as well as for state and federal governments to require safety training.

History of Motorcycle Use

Gottlieb Daimler and Wilhelm Maybach invented the first internal-combustion, gasoline-fueled motorcycle, called the Petroleum Reitwagen, in Bad Cannstatt, Germany, in 1885. While the Germans were the pioneers of motorcycle production, the Americans soon took the lead. In 1906, after many trials and errors, William S. Harley and Arthur Davidson established their first motorcycle factory in Milwaukee, Wisconsin. Police departments served as their first customer base,

Motorcycle Safety

There are approximately 200 million motorcycles in use around the world today. This count includes motorcycles, motor scooters, mopeds, and other similar motorized bicycles. Because motorcycles

and motorcycle racing among civilians became a popular pastime.

The U.S. military, perhaps, did the most to boost Harley-Davidson's influence on the motorcycle market and to further development of motorcycles and similar vehicles around the world. In 1916, General John "Blackjack" Pershing placed the first formal order with Harley-Davidson for motorcycles to use during the United States–Mexican border conflict. In 1917, the U.S. military demanded motorcycles from Harley-Davidson and Indian, another American motorcycle company, during World War I. When U.S. Corporal Roy Holtz was the first American to enter Germany on a Harley one day after the Armistice, the Harley-Davidson motorcycle became a symbol of American freedom and democracy. During World War II, Harley-Davidson supplied the United States and its allies with motorcycles. Their popularity among servicemen inspired Harley-Davidson to publish *The Enthusiast*, a magazine for motorcycle fans. The U.S. military continued to employ Harley-Davidson motorcycles in Japan, Korea, and Vietnam, as well as more recently in Iraq and Afghanistan. The growing worldwide popularity of motorcycles spurred manufacturing in Asian countries. Honda, Kawasaki, Suzuki, and Yamaha are among the Asian brands now being sold in the United States.

Over the years, military veterans and supporters purchased motorcycles from Harley-Davidson for civilian use. Motorcycle clubs began to form around mechanics' garages; while some groups came together for the shared joy of riding or racing, others combined motorcycle riding with criminal activities. Motorcycle riders are also perceived as people who valorize or flaunt risk. Gay pride parades often start with "Dykes on Bikes," motorcycles ridden by members from the lesbian motorcycle club with 22 chapters across the United States.

In contrast to the daredevil stereotype, safe motorcycle operation is promoted by national organizations such as the American Motorcyclist Association (AMA), which encourages safety, advocates for motorcyclists' interests, and sanctions races and events.

Motorcycle Safety Precautions

To prevent accidents, motorcyclists use "personal protective equipment" (PPE), also known as



A member of the U.S. Air Force works on some cornering exercises on a high-powered sport motorcycle at Ford Island, Hawai'i, during a military sport bike rider course that offered specialized training for military sport bike riders, June 2008.

"motorcycle gear." PPE provides improved visibility for the motorcyclist and other drivers, abrasion resistance, impact protection, and weather protection. In many countries, certain articles of PPE are required, and motorcycle manufacturers and governments recommend their use. Motorcycle gear includes a helmet, gloves, jackets, long pants with special protection for the knees and hips, boots, goggles or helmet visor, ear plugs, and vests in highly visible, reflective material. A full face helmet is recommended; the National Highway Traffic Administration assures motorcyclists that it does not interfere with vision or hearing.

U.S. military service members are required to wear a helmet, gloves, long-sleeved shirts, and over-the-ankle footwear or certified motorcycle boots when driving motorcycles. A motorcycle jacket with padding is also recommended

to reduce trunk and arm injuries; such a jacket is mandatory for German motorcyclists. These policies have been adopted into some state laws regarding civilian motorcycle operation but not nationwide. Most motorcycle riders take precautions to avoid windburn and flying debris during their rides by wearing leather jackets, long pants, helmets, boots, and bandannas, but riders of smaller, lighter motorbikes and scooters often ride without as much protective gear.

Motorcycles themselves include various safety features. New motorcycles must include headlights that turn on once the engine is started, crash bars to protect a rider's legs and engine from injury during a rollover or collision, and an antilock braking system that makes it easier and safer to stop the motorcycle. Yamaha and Suzuki are currently testing airbag devices on motorcycles.

Motorcycle Safety Training Programs

People interested in riding a motorcycle should contact their state department of motor vehicles (DMV) for information on licensing. The potential rider will often have to meet an age requirement, pass written and vision tests, and pay a permit application fee in order to acquire their learner's permit. While active-duty military and veterans might have received motorcycle safety training in the service, most states will not accept this training in place of passing state-approved tests.

Each state allows different time frames, ranging from 20 days to at least six months, to prepare for the road test in order to acquire a motorcycle license. Potential drivers must provide a "street legal," registered motorcycle for their road test. After passing the road test, some states will add a "motorcycle endorsement" on the new rider's driver license, if they have one, or print a separate license with photo identification.

The Motorcycle Safety Foundation (MSF) is a national not-for-profit organization sponsored by BMW, Harley-Davidson, Honda, Kawasaki, Suzuki, Yamaha, and other motorcycle producers. Established in 1974, MSD developed the Rider Education and Training System (RETS) and promotes continual safety education for riders and trainers known as "RiderCoaches." More than 2,700 so-called RiderCourse sites exist throughout the United States to provide basic RETS. MSF also lobbies the government for safer riding

environments, motorcycle safety research, and state training and licensing programs.

Approximately 400,000 motorcyclists enroll in MSF courses each year, and some states will waive their on-bike riding skills test and/or their written test if a rider has an RETS Course Completion Card. The MSF *Motorcycle Operator Manual* is the model for many state DMV reference handbooks for motorcycle applicants; they also provide a "Sharing the Roadway" booklet for nonmotorcyclists to help prevent collisions. Forty-five states have a state motorcycle safety coordinator. Most operate through a state-approved motorcycle safety program, a highway safety office, a driving school, or a DMV. The safety coordinator can tell potential riders whether or not RETS is available or recognized in their state and how to apply for their program.

Since the occupation of Iraq, the U.S. Army has noted a dramatic increase in motorcycle-related injuries, hospitalizations, and deaths among service members, mirroring this phenomenon in the civilian world. Researchers found that young men, Marines, people on combat duty, and those with no education past high school were most at risk for accidents.

Nearly half of motorcycle fatalities involve a rider under the influence of alcohol or drugs. Automobile-centric motor vehicle laws do not always specify that driving a motorcycle under the influence is also illegal. As the motorcycle accident rate remains so high, it is crucial that any motorcycle education program stresses the importance of driving sober and well rested.

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See Also: Automobile Accidents and Prevention; Driver Licensing; Highway and Road Safety; Motorcycles; Speed Laws and Enforcement; Traffic Laws and Enforcement; Traffic Safety.

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Motorcycles

The motorcycle mystique evokes feelings of power, speed, and freedom of the open road in people, whether or not they are cyclists themselves. Motorcycles evolved from simple, steam-powered bicycles to streamlined, powerful machines that have existed nearly as long as automobiles. Motorcyclists have developed a mystique and psychology of their own to go along with their machines.

Even in its early years, both athletes and spectators saw the motorcycle's potential for transportation as well as racing and sport, and they demanded more powerful, versatile, and comfortable machines. By the first decade of the 1900s, engineers for American motor cycle designers like Indian and Harley-Davidson experimented with twin cylinder engines that became standard on most motorcycles. By the start of World War I in 1914, the motorcycle had evolved from an experimental primitive machine to dependable, speedy, and inexpensive transportation.

By the end of World War I, motorized tanks and airplanes were common equipment and during the 1920s BMW, Moto Guzzi, and Triumph began producing their first motorcycles with great success especially in Europe. Despite competition from the automobile, American motorcycle sales remained

relatively stable throughout the 1920s. The Depression of the 1930s forced several motorcycle companies out of business while others barely survived. After the Second World War, the motorcycle manufacturing industry enjoyed a boom in sales that lasted through the 1950s. Europeans wanted cheap transportation because of austere wartime economic conditions, and the more economically sound American consumers snapped up dirt bikes and larger capacity motorcycles, escalating motorcycle sales to peak highs for the decade of the 1950s. With European manufacturers dominating the market, only Harley-Davidson survived as an American manufacturer of motorcycles.

Motorcycle technology also improved during the 1940s and 1950s, including advances in suspension, dual seats and sidecars, and push button ignition, but aging motorcycle design and engineers encountered growing competition from the automobile industry. In the 1960s, Japanese companies increasingly challenged the Western motorcycle market with their sophisticated Hondas, Suzukis, and Yamahas. Initially, Japanese motorcycles made only small inroads in the Western market until consumers learned how to operate the Japanese machines that featured superior technology and strong performance. Soon Japanese motorcycles outmatched contemporary European and American manufacturers and by 1970, Honda had introduced its pioneering four-cylinder, four-stroke engine that introduced a generation of enhanced motorcycles. The growing sport of motorcycle racing also promoted motorcycle manufacturers to improve the two-wheeler motorcycle with more powerful engines and more reliable braking. During the 1980s and 1990s, manufacturers built more powerful and technologically sophisticated motorcycles and the motorcycle grew in importance as a symbol of speed and the magic and freedom of the road.

To 21st-century enthusiasts, motorcycles are much more than transportation; they symbolize status and freedom. Modern motorcycles have evolved from the early days of the two wheeler to computerized technology and custom bikes for different purposes. Cyclists can choose sport bikes, off-road bikes, scooters, and super and customized bikes. Future motorcycle designs such as new versions of leg protectors and air bags ensure continuing technological designs, but safely will remain an important consideration in motorcycle design.



Members of the Rolling Thunder advocacy group on the Memorial Bridge in Washington, D.C., May 2009. This annual ride brings attention to the issue of prisoners of war/missing in action (POW/MIA) service members from the Vietnam War and other wars. The rally and ride, which culminates in a stop at the Vietnam Veterans' Memorial, included over 500,000 motorcycles in 2013.

The Motorcycle Mystique

Technology has enhanced the safety features and low gas mileage of motorcycles. The pleasure of racing on the open road has contributed to the motorcycle mystique, as have the proximity of the motorcyclist and surrounding environment and the skill and knowledge required to ride the razor's edge between danger and safety. British motorcyclist and historian T. E. Lawrence who logged at least 100,000 miles of his life on motorcycles and eventually died on a motorcycle, summarized the speed mystique of motorcycles for most riders when he said, "...I could write for hours on the lustfulness of moving swiftly." All of these factors have contributed to the motorcycle image, but social not mechanical traits dominate the motorcycle mystique.

Motorcycles and their riders have a complex social history, with the modern motorcycle image beginning in the 1930s and continuing with motorcycle clubs after World War II and their impact on media and culture. In the late 1930s, Linda Dugeau of Providence, Rhode Island, loved motorcycles and

she thought the other women who owned and treasure their motorcycles should meet and share their enthusiasm. She wrote to motorcycle dealers, other motorcycle riders, and anyone else she thought might know women motorcycle riders, and she finally produced a list of women motorcycle enthusiasts. In 1940, Linda Dugeau founded the Motor Maid organization with 51 charter members, and the American Motorcycle Association issued Charter #509 to the Club in 1941. The Motor Maids have maintained their identity and governing structure since then, making a valid claim to being the oldest established motorcycle club in the world.

In his motorcycle history, *Born to Be Wild*, writer Paul Garson tells the story of American GIs returning home from World War II and creating motorcycle clubs as a way of coping with the transition into civilian life. Although the reasons for the clubs were complex and psychological, including recreating the camaraderie of the service, motorcycle clubs became popular and weekend gatherings of hundreds of riders commonplace.

Most motorcycle gatherings were peaceful, but during a large 1947 rally in Hollister, California, several motorcycle clubs erupted into violence. Local police arrested approximately 60 riders for mostly minor offenses, but they felt so outnumbered by the number of cyclists that they called the state highway patrol for assistance. Newspapers and other media soon dubbed the event “The Hollister Riot.” *The San Francisco Chronicle* called the incident an “outburst of terrorism,” claiming that 4,000 motorcyclists had captured the town, and *Life Magazine* staged photographs of beer and bikers. Although reports of biker behavior at Hollister were later found to be exaggerated, “the Hollister Riot” had already created the myth of the lawless, problem biker in the public imagination. Films like *The Wild One* in 1953, with Marlon Brando portraying the rebellious cyclist Johnny Strabler, symbolized the public perception of motorcycle culture and inspired generations of young motorcycle enthusiasts.

Different versions of the Hollister idea has been repeated through the decades after the 1940s as have differing versions of the founding of the Hells Angels motorcycle club, but the media reacted to motorcycle clubs in the same way. Newspapers, magazines, and radio and television stations nationwide tended to emphasize and exaggerate stories of lawless cyclists, ravished women, and outlaw culture. The 1950s fears of juvenile delinquency and the stormy culture seas of the 1960s expanded the motorcycle mystic in different directions and made cyclists even more controversial. Many people considered groups like the Hells Angels symbols of cultural deterioration while others like Sixties radicals and academics saw them as antiheroes. A resurgence of biker films in the 1960s and 1970s, including *The Wild Angels* (1966), *Cycle Savages* (1969), and the classic *Easy Rider* (1969), added to the myth of motorcyclists as modern cowboys, challenging the rigidity and conformity of American culture.

Yet, the contrasts between the image of the rebellion and even lawlessness of motorcycle riding are ironic. There are established standards of dress and behavior for motorcyclists. Black leather and helmets are classic styles for safety as well as image reasons. Motorcyclists may think they are free, but their machines are not free and they have to operate within a modern consumer economy to afford their motorcycle freedom.

Twenty-First-Century Motorcycles

Motorcyclists wave to each other on the road without social screenings or class connections and participate in important commemorations like the annual journey to the Vietnam Veterans’ Memorial. Motorcyclists in the 21st century ride into the heart of the true meaning and importance of motorcycling when they share the community and experiences that transcend nationality, gender, race, and the other dividers between human beings.

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See Also: Automobile Accidents and Prevention; Automobile Culture; Driver Licensing; Motorcycle Safety; Single-Occupant Vehicle Trips; Traffic Laws and Enforcement.

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Moving Ahead for Progress in the 21st Century Act

The Moving Ahead for Progress in the 21st Century Act, or MAP-21, was passed by the U.S. Congress by wide majorities on June 29, 2012, and signed into law by President Barack Obama a week later. A surface transportation funding reauthorization bill, MAP-21 keeps federal spending about the same in the two years to which it applies but enacts reforms that the Congressional Budget Office estimates will

reduce the federal budget deficit by over \$15 billion by 2022.

MAP-21 was introduced in the House by John Mica (R-FL) as H.R. 4348 on April 16, 2012, and passed the House 293-127 on April 18. It passed the Senate by unanimous consent on April 24. After being reported by the joint conference committee on June 28, 2012, the final bill was agreed to by both the House (373-52) and the Senate (74-19) on June 29. Although the bill was introduced by a Republican, Republicans were the only ones to vote against the bill.

Overall, MAP-21 reduces transportation expenditures by consolidating the number of funding programs. It also calls for the development of a national freight policy and gives states and other recipients of federal transportation funding significantly more flexibility in how they spend that funding. A total of \$118 billion was authorized for surface transportation programs over 27 months, extending then-current federal funding through fiscal year 2014 and maintaining funding levels and gas tax revenue share of public transit at present levels. Long-term transportation financing was not addressed, and it will either be addressed in 2014 or Congress will again have to consider legislation to extend previous spending levels as a stopgap measure.

The consolidated transportation programs include four core programs: The Highway Safety Improvement Program, the Congestion Mitigation and Air Quality Program, the Surface Transportation Program, and the National Highway Performance Program. The Highway Safety Improvement Program is the same as under the previous act, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy For Users (SAFETEA-LU), as is the Congestion Mitigation and Air Quality Program. The Surface Transportation Program, already extant, grew by absorbing several SAFETEA-LU programs. The new National Highway Performance Program was created by combining the Highway Bridge Program, Interstate Maintenance, and the National Highway System funding program.

MAP-21 followed the previous transportation funding bill SAFETEA-LU, which was signed into law on August 10, 2005, and expired on September 30, 2009. Though remembered largely for the \$200-million "Bridge to Nowhere" in Alaska, SAFETEA-LU was an important bipartisan transportation bill that went far beyond highway funding to

grant much-needed federal funding support to public transportation, bicycle programs, pedestrian programs, and other areas.

Criticisms

MAP-21 drew sharp criticism from many quarters, especially in contrast to the 2009 stimulus bill, which had called for widespread transportation infrastructure improvements and an increase in federal development of green jobs. Bicycle and pedestrian programs were merged into a Transportation Alternatives (TA) program with reduced funding, half of which is given to the states. The other half is disbursed to the metropolitan planning organizations (MPOs), created by the Federal-Aid Highway Act of 1962, of which there are now 342. Also within TA are road work, environmental mitigation, a recreational trails program, and the Safe Routes to School program, making it likely that an insignificant amount of the TA funds, already considerably reduced from the previous law, will go to bicycle programs.

Private sector funding and alternative funding mechanisms for highway and transit projects were increased. Electric vehicle charging and natural gas fueling stations were acknowledged as valid uses of funding from MAP-21's core programs. The deficit reductions created by MAP-21 are brought about without increasing transportation costs on the user end, making it 20 years since the federal gasoline tax was last increased, in 1993. Instead, revenue is created through an assortment of means, both inside and outside the transportation sector.

For instance, businesses that make roll-your-own-cigarette machines available to consumers were defined as tobacco manufacturers and required to pay a tax. Department of Transportation expenses were reduced by the repeal of an older requirement that the department reimburse the difference in cost for shipping foreign food aid on an American flag ship. Changes were also made to the way pension plans work, and certain federal employees were allowed to enter into a phased retirement in which they would draw part of their pension while continuing to work full-time.

Review Process

MAP-21 also streamlined the environmental review process, excluding many projects from the need for review and imposing a four-year deadline on

the process, less than half of the average time. The changes to the environmental review process were a significant victory for the conservative Republicans, who have traditionally opposed “big government” in the form of environmental regulations and review processes that they claim slow down the business of industry. The streamlining of the process reduced the role of the public in the planning of transportation projects by removing the public comment phase on water, air, and public-safety impacts. Public participation in the review process of activities with environmental impact has been a key element of federal environmental policy since President Richard Nixon signed the National Environmental Policy Act into law in 1969.

The streamlining of the review process, detailed under the Accelerated Decision Making portion of the bill, is given teeth by imposing a fine on federal agencies that do not meet the four-year deadline. The fine consists of a maximum of 7 percent of the agency’s fiscal year budget. Critics have pointed out that this creates a situation in which federal agencies seeking to avoid the fine are equally motivated to deny permits and to rush the environmental review process. Advocates point out that environmental reviews have in recent years ballooned into a lengthy and cumbersome process, and that four years should be sufficient time to address the public’s concerns and invite comment.

Projects exempted from the review process include all those with less than \$5 million in federal funding, or under \$30 million in funding when less than 15 percent of the funding is from federal sources. However, critics say there is no reason to think that funding levels are an adequate indicator of the presence, scope, or severity of potential environmental impact, or of the public’s interest in that environmental impact. Exemptions are also extended to “operational right of way” projects, which are transportation projects on property already used for transportation projects. This exemption has fewer critics. Categorical exemptions to environmental review apply to projects of infrastructure repair or new construction in response to a natural disaster.

Omissions

MAP-21 was also criticized for what it left out. For example, both the Keystone XL pipeline and coal ash regulations were put off to another time, and

potentially another Congress, just as this bill was itself something that had been put off for several years. The law also did not include \$1.4 billion for the Land and Water Conservation fund, which many hoped would be reauthorized so that lands in need of protection could be acquired.

A much-discussed provision to develop design standards to ensure that the transportation infrastructure could endure extreme weather was also removed from the final version of the bill. Perhaps worse, from an infrastructure-minded standpoint, the bill eliminated dedicated funding for transportation infrastructure repairs. Advocates of this elimination point out that this does not mean repair funding is not available; it is applied for in the same way that new projects apply for their funding. However, critics point out that dedicated funding is needed for repairs to bridges, highways, tunnels, and other transportation infrastructure throughout the country, especially when the frequency of extreme weather in the 21st century would seem to pose a particular danger to unrepaired infrastructure.

Other Provisions

Like many acts of Congress, MAP-21 included several riders unrelated to the bill’s main purpose. It extended federal student loan rates through June 2013, extended the Secure Rural School Acts by one year, authorized \$346 million for payments to heavily forested communities to compensate them for revenue lost by federal logging limitations, and reauthorized the national flood insurance program until 2017. In addition, \$2.4 billion was transferred from the Leaking Underground Storage Tank (LUST) fund to the Highway Trust fund, although the bill did not divert future LUST revenues as the Senate version of the bill proposed.

Another provision tied the spending of the Harbor Maintenance Trust Fund to its annual receipts. The act also called for an environmental impact study of Asian carp, motivated by concerns that the fish that has already infested the Mississippi River and its tributaries could enter the Great Lakes. Payments to states completing abandoned mine reclamation projects at the government’s request were capped at \$15 million annually. MAP-21 also included the The Resources and Ecosystems Sustainability, Tourist Opportunities and Revived Economies of the Gulf Coast States Act (RESTORE), which invests federal funding in Gulf

Coast restoration in the wake of the BP-Deepwater Horizon oil spill disaster. The act designates that 80 percent of the Clean Water Act penalties from BP's settlement of the 2010 disaster—which could reach \$21 billion—must be used for assistance to and the restoration of the communities, waters, coastlines and natural areas damaged by the spill.

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See Also: Federal Aid Highway Program; Intermodal Surface Transportation Efficiency Act; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Surface Transportation Program; Transportation Equity Act for the Twenty-First Century.

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Multiple Criteria Decision Making/Aiding

Up against myriad urban problems, diverse social and economic issues, and a limited financial budget, it might seem not just difficult but almost impossible to create a balance and identify the projects that would bring about the greatest benefits to society. Yet, planners all around the world strive to achieve that balance and prioritize their investments into the best projects. It is this balancing act that can be aptly termed "multiple criteria decision making" (MCDM), because it involves making decisions based on multiple criteria. While MCDM could relate to any field

or subject, in the context of transportation, it relates to how MCDM has been an effective tool in making public investment decisions such as project selection and prioritization.

In matters of public investment, budget constraints are always present, and it is vital to assess the contribution of a particular project to public welfare, as well as to choose a project with maximum welfare potential. However, there is a never a single decision maker behind project selection, and that decision is always made as a result of group discussions and compromises.

The decision-making process, in itself, is a significant factor in selecting a project, and recognition of this fact has led to the development of a framework of analysis for decision making where projects are analyzed against a set of criteria. This analysis framework can be called a decision-making support system (DSS). A DSS is usually a computer-based information system used to support decision-making activities in situations where it is not possible or desirable to have an automated system performing the entire decision process. A DSS also makes it easier to interpret multiple criteria, leading to faster and more efficient decision making. So, what are the different criteria and how are they assessed to make decisions?

Cost-Benefit Analysis

For a long time, cost-benefit analysis (CBA) has been the preferred tool to analyze the value of a project. The aim of using CBA is to be able to see if the benefits of a project are more than the costs involved, in which case a project can be called financially beneficial. CBA tries to monetize all benefits and costs of the project and finally arrives at a net present value (NPV) and an internal rate of return (IRR) upon which a project's financial feasibility is assessed. Initially used by private enterprises for private projects, CBA helps quantify the purely financial returns that a project is capable of delivering. Gradually, its use was extended to public projects, as well.

However, public bodies and public projects do not only have financial objectives to achieve. It is vital for the public projects also to attain maximum socioeconomic benefits. This means that certain parameters—such as time, safety, leisure, happiness, clean air, environmental preservation, and others—must also be measured. Unfortunately,

these parameters cannot be computed in the CBA model because they do not carry financial value. To analyze projects with such demands, social cost benefit analysis (SCBA) was carried out, until it was realized that SCBA could not entirely handle the assessment of projects that have impacts without direct monetary valuation.

Multiple Criteria Assessment

Thus, the need arose for a tool that enables assessment of various criteria that may or may not be assigned a financial value. This led to the development of the multiple criteria assessment (MCA) approach, where multiple criteria are measured in different units, not necessarily in monetary units, and aggregated using a function representing the decision maker's preference. MCA differs from CBA and SCBA in more than one way. While the primary aim of CBA is to identify the project with maximum financial benefits, MCA is used to determine the extent to which a project achieves a predetermined set of goals or objectives.

In the MCA process, all impacts of the project(s) are listed and weighted for their importance to the achievement of overall objectives. The project with highest score and best performance is then chosen for implementation. The objectives could be as defined under a policy statement or a development plan. For example, the objectives of a transport policy could be higher use of public transport, reduction in pollution levels, higher mobility in the region, and equitable distribution of goods and services. Various projects—such as a bus rapid transit (BRT) project, a light rail system, highway expansion, or constructing new roads—can all be assessed in MCA, and the project that achieves the objectives to greatest extent would be chosen for implementation.

MCA also takes into account the preferences of the decision maker(s) when all impacts of a project are weighted for their importance. The weights are assigned based on the decision maker(s)'s assessment of relative importance of the different criteria; hence, the results are not completely objective in nature. Due to the subjectivity in the weighting of parameters and criteria, there is always a possibility that the results could be manipulated and there is always some doubt about the robustness of its results.

Some experts also argue that MCA carries the danger of arbitrary assessments, and it might also

lead to double counting. MCA does not assess the worth of a project with regard to budget issues, although CBA provides specific results and numbers that are required for making budgetary decisions.

In view of all its pros and cons, it can be said that MCA is a good alternative only when projects involve important impacts that cannot be monetized, or if explicit attention needs to be paid to the perspectives of the decision makers. MCA might also be preferred when it is vital to consider the perspectives or preferences of involved stakeholders. More often than not, a decision on project selection does not depend on the wishes of one person but is a compromise among many different parties. For projects where all parameters cannot be given monetary value, MCA can identify all the relevant issues for several decision makers and rank the projects under various hypothetical sets of weights. That is, for n number of projects and w number of decision makers, there will be n times w options to choose among. The weights are not assigned based on the preferences of one decision maker, but all, and in the end, the group must choose one particular set or a combination of them.

Combined Platform

Despite the differences between CBA and MCA, both of these tools are increasingly seen as complementary rather than competitive. A middle path can be created wherein the advantages of both methods can be amalgamated to achieve the most comprehensive results. A pure MCA exercise could fail in almost all projects because the decision makers, due to political and other motivations, might never reveal their true objective preferences for certain criteria over others. Therefore, CBA and MCA can transition together into a DSS that presents all the facts before the decision makers, who can then make an informed decision and choose the alternative that is acceptable to the majority.

In that way, the DSS, like a CBA, can give the IRR and NPV and monetize the parameters that are used in SCBA. It also has an MCA module where a number of nonmonetary criteria are included and weighted by the users, with results derived to support the decision makers' assessment of all projects. Once all the parameters have been analyzed, the group of decision makers can then use all the information to discuss, argue, bargain, and finally choose the most agreeable option. Such a combined

platform can be called a DSS in the true sense that it aids in MCDM. When embedded into a geographic information system (GIS) platform, DSS becomes SDSS (spatial decision support system), which increases its transparency, repeatability, and user-friendliness.

An example of using DSS in MCDM is the EUNET project. In the 1990s, the European nations collectively wanted to improve their Trans-European Transport Network (TEN-T) to reduce regional disparities. However, there was uncertainty regarding the effects of various transport project types. The participating nations of European Commission were not sure which project would bring the most benefits. The EUNET project was initiated and funded by the European Commission with the aim of developing a comprehensive methodology to assess the impacts of transport initiatives, infrastructure investments, and regulatory and fiscal policies in the European Union region.

Under this program, a broad-based modeling system was developed to support policy decisions. The modeling system included an assessment framework that combined both CBA and MCA methods to value socioeconomic effects of a project. The model was demonstrated for the Trans-Pennine corridor in the United Kingdom and for long-distance freight movements in Finland. EUNET also provided an overview of current practice across European nations in appraising major

transport projects and deriving monetary values for impacts.

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See Also: Benefit–Cost Analysis of Transportation; Risk Analysis/Assessment; Transportation Planning; Travel Demand Forecasting.

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Encyclopedia of
TRANSPORTATION



National Airspace System

The U.S. National Airspace System (NAS), administered by the Federal Aviation Administration (FAA), has responsibility for civil airspace over the United States and portions of the world's oceans. It is among the most complex, highly regulated global aviation systems. Flight safety is the primary goal of the NAS, followed by the secondary goals of expediency and efficiency. Air traffic congestion, terrorism and heightened security, economic downturns, aging infrastructure, and environmental concerns threaten the FAA's ongoing achievement of these goals. The FAA began development of the NAS redesign project, known as NextGen, to meet these concerns.

The need for safe and efficient air traffic control followed the explosive development of commercial aviation since World War II. The United States had become a global leader in terms of airspace use, as well as aircraft manufacturing and operation, by the end of the 20th century. Technological advances increasingly allowed pilots to fly relying solely on instruments in conditions of poor to no visibility, but air traffic control must maintain safe aircraft separation. Rising media coverage and victim counts in both ground and in-air aviation accidents also put public pressure on the federal government to better control its airspace.

The U.S. federal government created the NAS in response to these needs. The FAA publicizes its operational guidelines for the NAS in the *Federal Aviation Regulations/Aeronautical Information Manual* (FAR/AIM) series, among other print and Web-based publications.

The NAS also oversees the use of airport facilities, the Air Traffic Control (ATC) system, the designation of flight rules and procedures, and airspace system users. As of 2013, the NAS had 41,000 operational facilities under its control, including over 19,000 airports and 600 air traffic control facilities, according to FAA statistics. The NAS employs approximately 14,500 air traffic controllers, 4,500 aviation safety inspectors, and 5,800 technicians to serve an average of approximately 50,000 flights daily.

Objectives related to the overarching goals of safety, expediency, and efficiency include the prevention of flight conflicts and delays, the efficient use of flight paths, increased productivity and capacity, improved service, and the minimization of costs.

When events such as the 1981 air traffic controllers' strike or the 2013 implementation of mandatory federal budget cuts, known as sequestration, led to workforce reductions, flight delays and reductions resulted. From the viewpoint of NAS, capacity, cost, and convenience would have to be sacrificed rather than safety.

Flight Operations

Pilots operate under two categories of flight operations: Visual Flight Rules (VFR) or Instrument Flight Rules (IFR). Guidelines for operating under VFR or IFR are based on established meteorological criteria for visual flight conditions (VFC) or instrument flight conditions (IFC), such as visibility. These guidelines vary by airspace.

The establishment of VFR and IFR assists in the maintenance of safe separation between aircraft to avoid collisions. Separation distances are mandated by aircraft type, weather conditions, and the flight rules in effect. Pilots operating under VFR rely on visual identification of other aircraft and, when necessary, they perform maneuvers to avoid collisions, a process commonly known as see-and-avoid. Pilots operating under IFR rely on air traffic controllers for clearances, information on other aircraft in the vicinity, and, if necessary, any evasive maneuvers required.

IFR requires proper aircraft instrumentation and the pilot's passing of an instrument flight examination. When traveling through controlled airspace, pilots operating under IFR must also file a flight plan with the FAA, which provides relevant information about the aircraft, planned route, and passengers. Pilots operating under VFR also often file flight plans for safety reasons, even though they are not required to do so. Pilots are not allowed to operate under VFR if the established meteorological guidelines for that airspace are not met. Many pilots choose to operate under IFR for added safety, even if conditions are right for VFR.

Airspace Classifications

The FAA designates two main classifications within the national airspace: controlled and uncontrolled. Controlled airspace encompasses the area around heavily trafficked airports, along aircraft routes, and above 18,000 feet. The designation of controlled airspace allows for the safe and efficient movement of aircraft through the nation's busiest airspace and airports. IFR air traffic control services are available to any flight operating in controlled airspace, but not all flights must be controlled.

The FAA further classifies airspace into six classes: A (Alpha), B (Bravo), C (Charlie), D (Delta), E (Echo), and G (Golf), each of which is governed according to different flight rules, based on International Civil Aviation Organization airspace

classifications. The United States does not use the Class F airspace classification. Factors that designate airspace classification include location, size, services, and aircraft and pilot requirements. Each classification is governed by its own set of flight rules. A, B, C, D, and E are controlled. These classifications have been established with the primary goal of managing flights operating under VFR in controlled airspace, as ATC automatically manages flights operating under IFR.

Class G (Golf) accounts for uncontrolled airspace. "Special Use" and "Other" airspace classifications can include alert areas, military operations areas (MOA), prohibited areas, restricted areas, and warning areas. Airports operating within uncontrolled airspace may or may not have local operational air traffic control towers. The allowance of uncontrolled airspace frees air traffic controllers to concentrate on directing traffic within the often-congested controlled airspace.

Class A airspace encompasses all airspace from 18,000 feet up to and including 60,000 feet mean sea level (MSL) for the majority of the United States, with the exception of the Hawai'ian Islands. Class A is the most controlled of the six airspace classifications. Class B is heavily controlled airspace that encompasses the surface to 10,000 feet MSL around the U.S. airports that receive the most traffic. Class A and B are also respectively known as the positive control area and terminal control area.

Class C is individually designed controlled airspace at congested airports that receive lower traffic than their Class B counterparts. A typical Class C airspace usually extends 5 nautical miles in diameter with altitude up to 1,200 feet, and 10 nautical miles in diameter from 1,200 to 4,000 feet above ground level (AGL). All aircraft operating under VFR in Classes B, C, and D must maintain contact with ATC.

Class D is individually designed controlled airspace that usually extends 4 nautical miles in diameter, from the surface to 2,500 feet AGL. Class E, which encompasses most U.S. airspace, includes all airspace between the other four classes. Class G is uncontrolled airspace that extends from surface level to the Class E airspace above it, typically extending to a height of either 700 or 1,200 feet AGL. Aircraft may operate under VFR in Classes E and G airspace only under appropriate VFR conditions.



An Airbus A380 flies by the air traffic control tower at Wittman Regional Airport in Oshkosh, Wisconsin. While this airport is normally a less busy airport, when it hosts an annual experimental aircraft airshow it becomes the world's busiest airport by traffic movements. In the United States, controlled airspace encompasses the area around heavily trafficked airports, along aircraft routes, and above 18,000 feet. Airspace is also classified into categories that take into account the amount of traffic at an airport.

Air Traffic Control

The air traffic control system is a major component of the NAS, encompassing the airspace, facilities, equipment, and personnel; aeronautical charts and other information; and rules, regulations, and procedures necessary for the management of airspace use. ATC encompasses all aspects of flight, from departure, throughout the route, and to arrival. ATC provides assistance to aircraft, although the pilot and flight crew still bear ultimate responsibility for flight operations.

ATC maintains separation between aircraft, sequences arriving and departing flights, and allocates airspace and runways. ATC also provides flight planning, clearances, procedures, briefings, and in-flight navigation and advisories, while maintaining air-to-ground communication. Difficulties that can interfere with ATC performance include saturated air traffic levels, hazardous weather conditions,

individual facility outages, economic cutbacks, aging infrastructure, and personnel shortages.

Technological advances have allowed for communication between onboard flight management computer systems and ground-based ATC. ATC equipment and systems include VHF and UHF radios, Very High Frequency Omnidirectional Range (VOR) air navigation systems, nondirectional radio beacon Loran (Long Range Navigation) C, Controller Pilot Data Link Communications (CPDLC), Automatic Dependent Surveillance Broadcast (ADS-B), Global Positioning System (GPS), Instrument Landing (ILS) and Microwave Landing Systems (MLS), and ground-based radar systems. Both primary and secondary (beacon) ground-based radar systems are used for surveillance, with information transmitted from aircraft transponders. A separate surveillance system governs oceanic flights.

ATC facilities include Air Route Traffic Control Centers (ARTCC), Terminal Radar Approach Control (TRACON), and Flight Service Stations (FSS), as well as local airport air traffic control towers and ground controllers. This division of ATC services means that pilots communicate with a variety of air traffic controllers during the course of their flight. Pilots could receive preflight assistance or briefings and file flight plans through FSS, which also broadcast useful information such as weather conditions. FSS also could assist in locating lost aircraft or assisting aircraft in distress.

An ARTCC is responsible for air traffic operating under IFR within its regional sector of U.S. airspace while flights are en route between their departure and destination airports. Sectors are defined by geographical region, as well as horizontal and vertical limits. Each ARTCC has an air traffic controller and assistant controllers and its own assigned radio frequencies. Control of flights moving between regions is passed between the ARTCCs through a system of strict guidelines and procedures. ARTCCs accept flight plan amendments, issue clearances, maintain safe aircraft separation, issue traffic and weather advisories, issue collision-avoidance maneuvers, and assist distressed aircraft.

TRACON centers, located at major hub airports, coordinate with ARTCCs, assist arriving and departing flights, sequence and space aircraft, provide takeoff and landing clearances, and direct the flow of ground traffic around runways and gates. Terminal Radar Approach Cab (TRACAB) facilities often service smaller, lightly trafficked airports that do not house a TRACON center. ATC at terminal facilities employs both tower- and ground-based controllers. Controllers track aircraft visually or through radar and provide directions through radio communication or the use of signal lights.

Next Generation Air Transportation System

NAS capacity has been strained as a result of continued growth in air traffic since the late 20th century, which has led to congested runways and skies, travel delays, inefficiencies, and economic losses. Many current hub airports have already reached saturation levels, and they face additional projected passenger growth. Other issues—such as an aging infrastructure, increased fuel consumption and emissions, and rising fuel prices, as well as increased terrorism and heightened security after

the September 11, 2001, terrorist attacks—have also emerged as mounting concerns.

The FAA plans for the future through its mandated oversight of federal funding earmarked for airport expansion and redevelopment plans. The FAA has also responded to an increased volume of air traffic, which is projected to show continued growth, as well as other issues through a redesign of the NAS known as the Next Generation Air Transportation System (NextGen). NextGen is designed to cost-effectively optimize airspace use, improve performance, address terrorism and safety concerns, and mitigate environmental hazards, such as fuel use and emissions.

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See Also: Air Traffic Control; Air Traffic Flow Management; Airplane Navigation Systems; Federal Aviation Administration; Next-Generation Airports, Federal.

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National Ambient Air Quality Standards

In 1948, bustling steel mills and coke plants lined the Monongahela River, from Donora, a mill town

of 14,000 people, north to Pittsburgh, 30 miles away. The Donora Zinc Works, a subsidiary of United States Steel Corporation, covered four of those miles and employed 6,500 people at the peak of its operations. Local people considered the noxious fog that drifted from the Zinc Works the price they paid for good jobs. Then, between October 26 and 31, 20 people choked to death and more than 7,000 were hospitalized or fell ill because of the health effects of severe air pollution.

The Clean Air Act and Amendments

State and federal health officials investigating the Donora air pollution produced the first dynamic federal and state laws aimed at controlling air pollution and the beginning of modern efforts to evaluate and combat health threats from air pollution. Several state laws were passed as well as the Clean Air Act of 1963, establishing funding for studying and cleaning up air pollution. The Clean Air Act passed in 1970 created the Environmental Protection Agency (EPA) and assigned it a primary role in enforcing the law. The EPA has been responsible for a variety of Clean Air Act programs to reduce nationwide pollution.

In 1990, Congress amended the Clean Air Act, giving the EPA more authority to implement and enforce National Ambient Air Quality Standards applying to outdoor air throughout the United States, with the goal of reducing air pollutant emissions and focusing on cost-effective approaches to reducing air pollution.

Role of the Environmental Protection Agency

Under the Clean Air Act, the EPA sets limits on certain air pollutants and how much of them can be present in the air anywhere in the United States, and these limits help ensure health and protection from air pollution for all Americans. The Clean Air Act also gives the EPA the authority to limit the amount of air pollutants coming from places like chemical plants, utilities, and steel mills, and it monitors the effectiveness of its regulations.

The Clean Air Act ensures the implementation of national standards and strategies to control air emission standards and the EPA cooperates with the states to integrate and enforce them. Individual states may pass stronger air pollution laws, but they are not allowed to have weaker pollution limits than the ones that the EPA has established.

Role of State and Local Government

It is logical for state and local air pollution agencies to take the initiative in carrying out the Clean Air Act, because state and local agencies have a special understanding of the local and state industries, geography, housing, and travel patterns, and they can develop customized solutions. Under the Clean Air Act, a state is required to develop a State Implementation Plan (SIP) outlining how it will control air pollution.

A SIP is a collection of the regulations, programs, and policies that the state will use to clean up polluted areas and the state must involve the public and industries through hearings and opportunities to comment on the development of the plan. State, local, and tribal governments also monitor air quality, inspect facilities, and enforce Clean Air Act regulations.

National Ambient Air Quality Standards

The Clean Air Act mandated the EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. For the purposes of the air quality program, ambient air is defined as the outdoor atmosphere, but not areas within fenced or restricted access boundaries of industrial facilities. The EPA is required to set National Ambient Air Quality Standards (40 CFR Part 50) for all criteria pollutants and it must review these standards once every five years to determine if they are appropriate or if new standards are required to protect public health.

The Clean Air Act identifies two kinds of standards: primary and secondary standards. Primary standards call for providing a margin of public health safety, including the well-being of “sensitive” populations such as people with asthma and other respiratory diseases, children, and elderly people. Secondary standards ensure public welfare measures, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

An area that is found to have air quality as good as or better than the National Ambient Air Quality Standards for specified pollutants is called an attainment area, and one that does not meet the standards is considered a nonattainment area. An area can be in attainment for one pollutant and in nonattainment for others.

Six Principal Pollutants

The EPA has identified six principal air pollutants or criteria pollutants, based on a foundation of scientific studies conducted over a number of years. According to the EPA, the criteria pollutants are particulate matter, sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and lead, and they are measured as either micrograms per cubic meter of air or parts per million by volume, parts per billion by volume, and micrograms per cubic meter of air.

Particle or particulate matter pollution includes microscopic liquids and solids that are found in vehicle exhaust, industrial emissions, and other sources. The EPA concludes that particle pollution requires both primary and secondary measures of micrograms per cubic meter of air, depending on daily and yearly concentrations.

Sulfur dioxide is a by-product of coal-fired power plants, industrial sources, residential heating, and motor vehicles. The EPA evaluates it as a primary pollutant, measuring it in parts per billion by volume and assessing its potential damage by its level of concentration.

Carbon monoxide is emitted from incomplete combustion of fuels from cars, buses, trucks, small engines, boilers, and industrial operations. The EPA considers it a pollutant requiring a primary margin for public health safety not exceeding a level of 9 parts per million by volume per eight hours.

Nitrogen oxides come from many sources, including diesel cars, trucks, buses, power plants, and industries; and nitrogen dioxide is mainly produced by internal combustion engines. It can decrease lung function and increase the risks of respiratory problems. The EPA considers nitrogen dioxide a pollutant covering both primary and secondary criteria, depending on its parts per billion by volume concentration and the amount of time it is present.

Ozone pollution, the main element of smog, forms in the air when volatile organic compounds and nitrogen oxides react with sunlight. The volatile organic compounds that form ozone come from vehicle and industrial exhaust, evaporated gasoline, solvents, paints, and other sources. The EPA assesses it both a primary and secondary pollutant measuring it in parts per million by volume and measuring its effects by concentration and duration.

Lead existed long before humans and poses an environmental and personal risk through

mediums including air, drinking water, food, deteriorating paint, and dust. Before scientists fully realized the harmful effects of lead, manufacturers used it in paint, gasoline, water pipes, and countless other products. High levels of lead can cause convulsions, coma, and death, and lower levels of lead can adversely affect the central nervous systems and impair mental and physical development in children. The EPA considers lead both a primary and secondary pollutant and assesses its concentration by measuring micrograms per cubic meter of air.

Ambient Air Quality Monitoring Program

State and local agencies implement the Environmental Protection Agency's Ambient Air Quality Monitoring Program, which consists of three primary categories of monitoring stations: State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations (NAMS), and Special Purpose Monitoring Stations (SPMS), all of which measure the criteria pollutants.

The 1990 Amendments to the Clean Air Act required the implementation of a fourth monitoring station category called the Photochemical Assessment Monitoring Stations (PAMS), which measure ozone precursors, which are approximately 60 volatile hydrocarbons and carbonyl.

In the Ambient Air Monitoring Program, air quality samples are generally collected to determine compliance with or progress made toward meeting ambient air quality standards. Air quality samples can be used to activate emergency control procedures that prevent or ease air pollution or to observe pollution trends throughout the region, including nonurban areas. Air quality samples are collected to provide a database for research evaluation of effects, land use and transportation planning, development and evaluation of abatement strategies, and development and validation of diffusion models. Monitors are located in less than 1,000 of the 3,068 counties in the United States.

Attainment and Nonattainment

The attainment and nonattainment classifications are important components of the National Ambient Air Quality Monitoring Program. The best way to measure whether an area is in attainment is to install several ambient air monitors throughout the region or state to measure the concentrations

of pollutants in the ambient air. If the concentration of one or more criteria pollutants in a geographic area exceeds the regulated or threshold level of one or more of the National Ambient Air Quality Standards, the area may be classified as a nonattainment area. Areas with concentrations of criteria pollutants below the established NAAQS requirements are considered to be an attainment or unclassifiable area.

The SIP must be submitted to the Environmental Protection Agency for nonattainment areas. In its SIP plan, a state will develop its approach to reducing the pollutant levels in the air and any emissions of precursor pollutants, which are those pollutants that can form another pollutant in the atmosphere. The Clean Air Act's comprehensive approach to reducing criteria air pollutants covers many different sources and includes a variety of clean-up methods.

The Environmental Protection Agency maintains a list of nonattainment areas for all six principal pollutants on its Green Book Web site. Attainment designations for all states are listed in the Code of Federal Regulations. Many states publish their SIP in print or on their Web sites. It is common for states such as Pennsylvania, South Dakota, and Nebraska to have counties in both attainment and nonattainment.

Continuing Air Pollution

Air quality continues to improve across the United States, but over 40 percent of Americans still live in counties with unhealthy levels of particle or ozone pollution. According to the American Lung Association, California cities like El Centro, Fresno, Merced, Bakersfield, Los Angeles, and Modesto are at the top of the list for those with the worst year-round particle pollution. California cities also appear on the list of areas most polluted by short-term particle and ozone pollution. A combination of California's weather, agricultural methods, and vehicle and machine emissions create an air pollution hazard for the state.

Pittsburgh–New Castle, Pennsylvania; Cincinnati, Ohio; Middletown, Kentucky; and Wilmington, Indiana, also made the list for the worst year-round particle pollution. Nationally, over 131.8 million people live in areas with unhealthy pollution, up from 127 million in the 2012 American Lung Association report.



A U.S. Environmental Protection Agency researcher checking air monitoring equipment on Grand Isle, Louisiana, in 2010. There are hundreds of air quality monitors throughout the United States as part of the Ambient Air Monitoring Program.

The Clean Air Act and its National Ambient Air Quality Standards have reduced air pollution and significantly improved human health and the environment in the United States. Since 1970, the six criteria pollutants have decreased by more than 50 percent. Air pollution from large industrial sources including chemical plants, petroleum refineries, and paper mills have been reduced by nearly 70 percent, and production of most ozone-depleting chemicals has stopped. New cars are more than 90 percent cleaner and are slated to be cleaner in the future.

To counterbalance these air pollution gains, the U.S. gross domestic product (GDP) has tripled, energy consumption has increased by 50 percent, and vehicle use has increased by almost 200 percent. The balancing act between clean air, consumption, and commerce seems to be fated to continue in the 21st century.

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See Also: Air Pollution/Air Quality; Clean Air Act and Amendments; Environmental Protection Agency; Health Issues; Nitrogen Oxides; Particulate Matter; Sulfur Dioxide; Volatile Organic Compounds.

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National Energy Act of 1978

The National Energy Act (NEA) was ratified by the U.S. Congress in 1978 to address issues associated with existing and future supply, demand, and usage of energy resources. At the time of enactment, the United States was entrenched in an energy crisis resulting from inadequate domestic supplies of oil and natural gas amid swiftly escalating demand for those and other energy resources. The country was at risk of becoming more dependent on foreign energy supplies and more vulnerable to global market fluctuations and uncertainties, which could hamper the continuation of positive U.S. economic growth. The NEA was conceived as a means to empower the United States to gain better control over its energy resources, practices, and policies.

The National Energy Act is the collective name used to refer to five individual pieces of energy legislation proposed under U.S. President Jimmy Carter's National Energy Plan (NEP). It encompasses the Natural Gas Policy Act (NGPA), Public Utility Regulatory Policies Act (PURPA), Energy Tax Act, Power Plant and Industrial Fuel Use Act

(Fuel Use Act), and National Energy Conservation Policy Act (NECPA).

While modifications have been made to the various provisions over the years, the NEA largely has succeeded in bringing improved cohesion to the U.S. energy sector by way of diverse regulatory and market-based programs, initiatives, and incentives that support energy conservation, efficiencies in energy use, and alternative approaches to energy resources.

Global Context

The Organization of Petroleum Exporting Countries (OPEC) launched an oil embargo against the United States in 1973 as a protest against U.S. support for Israel during that country's territorial conflict with Egypt and Syria in October of the same year. The resulting supply shortage signaled the end of inexpensive gasoline in the U.S. market and fueled an already smoldering domestic oil crisis arising from low U.S. reserves.

Shortly after the embargo was imposed, OPEC announced that it would allow its member nations to set their own prices for their oil exports rather than continuing the practice of enabling oil companies to set their own price per barrel. As a result, the per-barrel price of oil rose by roughly 130 percent above pre-embargo pricing, representing a nearly 400 percent increase from the same period just one year earlier. The short supplies and soaring prices meant long lines at the gas pump and strong consumer demand for more fuel-efficient vehicles. American automobile manufacturers experienced sharp declines in sales of traditional gas-guzzling vehicle models and the U.S. auto industry plunged deeply into the expanding economic recession at home. The situation had reached crisis proportions by 1977.

It was against this backdrop that President Carter proposed his National Energy Plan to Congress. The original plan included more than 100 individual legislative and administrative proposals that ultimately became organized under the NEA umbrella. The components of the plan were designed to reduce U.S. dependence on foreign oil, limit supply disruptions, prepare for supply shortages caused by capacity limitations, and promote development of reliable, renewable sources of energy to facilitate sustained economic growth. Specifically, the NEA recommended an ambitious conservation program covering energy use in the transportation, building,

industrial, and power sectors as a means to reduce growth in annual energy demand. It also advocated for industry players who were using oil and natural gas as primary energy sources to convert to more prevalent forms of energy, such as coal and other fuels. Another key component of the energy plan included implementation of a rigorous research and development program aimed at providing renewable and alternative energy resources and technologies sufficient to meet domestic energy requirements. Tax incentives, pricing practices, and production policies were put in place to support the main components of the plan.

Components of the NEA

The NEA established a comprehensive national energy policy for the United States, supported by several targeted legislative acts.

The Natural Gas Policy Act (NGPA) extended price controls on sales of natural gas to include the intrastate market rather than interstate markets only. With the NGPA, all gas produced in the United States became subject to price controls. Previously, producers of natural gas took advantage of the disparity in regulatory rate control between interstate and intrastate markets and began directing the majority of their supplies to the uncontrolled intrastate market in search of greater profits from underpriced gas. As a result, there were repeated supply shortages in the interstate market, including significant shortfalls in regions served by interstate gas pipelines.

The NGPA also included provisions for phased deregulation of the wellhead price for new natural gas, which took place over the following nine years, and for an incremental pricing methodology that would distribute the expense of costly new gas to industry players versus residential users of natural gas. In addition, the act gave transportation authority to the Federal Energy Regulatory Commission (FERC). Specifically, the FERC was given the ability to authorize any interstate pipeline to transport gas on behalf of any intrastate pipeline or local distribution company without a certificate of prior regulatory approval, and likewise for any intrastate pipeline to transport gas on behalf of any interstate pipeline or local distribution company without a certificate. The provision separating natural gas transportation services from natural gas sales services marked an important step toward the

restructuring of the gas pipeline industry to create a competitive gas supply market.

The Public Utility Regulatory Policies Act (PURPA) was another key piece of regulation under the NEA. PURPA required public utilities to purchase power from independent companies that could produce power for less cost than what it would cost for the utility to produce the same level of power itself. The intent was to encourage more efficient energy production and increased development and use of renewable energy resources and technologies.

The Energy Tax Act provisions of the NEA focused on tax-based incentives to foster new energy production while reducing inefficiencies tied to price-controlled oil and gas. The tax incentives included residential energy credits aimed at encouraging consumers to make energy conservation investments for their homes. It also included business energy credits designed to encourage companies to invest in more efficient facilities and equipment and to increase production of renewable energy, alternative fuels, and high-cost natural gas. The Energy Tax Act incorporated a tax disincentive as well in the form of a gas-guzzler tax placed on low-fuel-efficiency vehicles.

The Power Plant and Industrial Fuel Use Act was implemented as part of the NEA to reduce dependence on natural gas and petroleum products. It sought to facilitate greater use of alternative energy sources by U.S. electric power plants and significant industrial installations by prohibiting those facilities from using petroleum or natural gas as a principal energy source without first receiving an exemption from the Department of Energy. When shortages in natural gas and petroleum products eased in the 1980s, the Fuel Use Act was repealed.

The final piece of NEA legislation was the National Energy Conservation Policy Act (NECPA). In addition to establishing energy-efficiency standards for new construction and strengthening energy-efficiency standards for home appliances, the act required federal agencies to conduct energy surveys in support of reducing consumption of non-renewable energy resources in buildings, vehicles, and various types of equipment. It also included a program to provide financial assistance to residential consumers to help them purchase and install solar heating or cooling equipment. Moreover, NECPA outlined an energy conservation plan for

federal buildings and created a program to provide grants and loan guarantees for energy conservation applied in schools, hospitals, local government facilities, and public housing developments.

Conclusion

With the National Energy Plan and resulting National Energy Act, President Jimmy Carter sought to increase the country's control over its own energy policies and practices. Many provisions of the NEA have been altered or abandoned in the decades since implementation in response to evolving economic and market conditions and needs. However, the conservation-focused regulations have remained largely intact and most of the market-based initiatives have been retained.

By the time President Carter left office in January 1981, the NEA had helped elevate U.S. petroleum inventories to record levels while also encouraging expansion of domestic exploratory efforts for new petroleum sources. At the same time, the NEA helped the United States generate a surplus of natural gas and devise a better means to distribute it fairly without unnecessary federal restrictions. The growth rate of U.S. coal production also doubled during President Carter's term, while imports and total consumption of oil declined significantly.

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See Also: Air Pollution/Air Quality; Alternative Fuels; Alternative Motor Fuels Act of 1988; Automobile Design; Automobile Emissions Controls; Carbon Dioxide Emissions; Carbon Monoxide Emissions; Congestion Mitigation and Air Quality Program; Deregulation; Energy Costs; Energy Policy Act of 1992; Energy Policy and Conservation Act of 1975; Environmental Impacts; Federal Transportation Policy; Low-Emission Vehicles; Motor Fuel Taxes; Pipeline and Hazardous Materials Safety Administration; Sustainable Transportation.

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National Environmental Policy Act

Transportation projects can harm the natural, social, cultural, and historic features of the environment in many ways. To prevent or minimize harm, a number of laws and regulations have been enacted since the 1960s. However, some deleterious impacts on the environment arising from infrastructure projects are unavoidable and, therefore, are allowed, but only if appropriate steps are taken during the planning phase of the process.

The National Environmental Policy Act (NEPA) spurred the development of a set of steps and procedures to follow; these are commonly referred to as the NEPA process. By following these procedures, a state department of transportation (DOT) or other lead agency can obtain permission for transportation projects that will have environmental impacts. The project sponsor or lead agency (often a state DOT) must offer and document a reasonable justification for any action that results in some type of environmental harm. In short, the NEPA process requires the creation of a document demonstrating that the transportation project was needed, that any environmental harm that occurs is either insignificant or could not be avoided, and that steps will be taken to minimize or mitigate whatever significant harm is likely to occur. The law does not prevent adverse impacts on the environment, but it does require all federally funded projects to consider environmental factors equally to other concerns in the planning of any agency action.

Protected Resources

NEPA broadly protects the environment, but it is not the only law that requires adherence to the NEPA process, which must be followed whenever a project impacts any resources protected by federal and state laws. Section 4(f) of the Department of

Transportation Act of 1966 protects publicly owned parks or land designated or administered as public parks, publicly owned recreation areas, wildlife and waterfowl refuges, and privately and publicly owned properties either on or eligible for the National Register of Historic Places. Historic properties are also protected under section 106 of the National Historic Preservation Act. The Endangered Species Act protects plants and animals threatened by extinction. The Clean Water Act protects wetlands, as does the Mitigation of Impacts to Wetlands and Natural Habitat—Final Rule. Adverse economic and social impacts to minority and low-income residents are protected by Executive Order 12898. There are additional acts that protect archaeological resources and resources on Native American reservations and burial sites.

Actors in the NEPA Process

State DOTs are often the lead agency for a project going through the NEPA process, but they are expected to consult with other government agencies and groups representing interested parties, depending on the resources impacted. Among those frequently consulted are the Federal Highway Administration (FHWA), Fish and Wildlife, the Environmental Protection Agency (EPA), the state historic preservation offices, and tribal councils.

Oversight of NEPA is a responsibility of the Council on Environmental Quality (CEQ), which reports to the president. The CEQ is charged with reviewing environmental impact statements, but each federal agency is free to generate its own regulations for the NEPA process, which are subject to guidance from the CEQ. The NEPA process calls for a good-faith effort to avoid or minimize environmental harm. It is a process, rather than a set of specific regulations.

NEPA functions as a framework for planning. According to the act, the president, federal agencies, and courts share responsibility for enforcing NEPA, but there is no direct enforcement mechanism. Resource agencies must be consulted and can approve or disapprove a project. This can delay a project but not stop it entirely. Ultimately, the courts have the final say as to whether the process was completed in an appropriate manner. Opponents can turn to the courts to claim failure to follow the NEPA process or to argue the likelihood of unnecessary environmental harm from a project.

The NEPA Process

All government agencies that use federal money on a project and all transportation projects that are under the jurisdiction of a federal agency must follow the NEPA process. The NEPA process also applies to all projects that impact a resource protected by federal legislation or executive order. Before such projects can be constructed, they must go through the process and be reviewed by the appropriate agencies having jurisdiction. The NEPA process enables federal agencies to make better decisions by calling for a review of the possible environmental effects of a project, if any. It also calls for reasonable efforts to avoid impacts or to minimize and mitigate those that do occur.

Depending on the possibility of an environmental impact from a specific project, the NEPA process ends with the production of one of the following types of official determinations: (1) a categorical exclusion (CE), (2) an environmental assessment with a finding of no significant impact (EA/FONSI), and (3) an environmental impact statement (EIS). Environmental review can be seen as occurring in a sequence. The first step involves ascertaining if the project is on a list for a categorical exclusion. If it is not on a list, then an environmental assessment (EA) must be conducted. If the EA finds no significant impact on the environment that cannot be mitigated, an EA/FONSI is issued. However, if there is a significant impact that cannot be mitigated, then an EIS must be produced.

A project can qualify for a CE if it is on a list of actions that have been determined to not result in significant environmental impact. Each federal agency creates its own list of CEs. The FHWA, for instance, lists these types of projects as potential CEs: construction of bicycle and pedestrian lanes, noise barriers, landscaping, and installation of signs and pavement markings.

As stated in 40 CFR 1508.9(a), an EA has three functions: (1) provide sufficient evidence and analysis for determining whether to prepare an EIS or a FONSI, (2) aid in agency's compliance with the act when no EIS is necessary, or (3) facilitate preparation of an EIS when one is necessary. Public hearings may be held but are not required. The completed EA will have these elements: the purpose and need for the project; alternatives, including the no-build option; the environmental impacts, if any, of the proposed action and of alternatives, along with the

mitigations that render the impacts insignificant; and a listing of the agencies and persons consulted. If the EA results in a FONSI, then it must contain an explanation of the reason(s) the project will not produce a significant environmental impact.

If a significant environmental impact is likely and cannot be mitigated, the agency must produce an EIS, which will require more intensive effort and resources. Often, there are two phases to the EIS process: the draft EIS (DEIS) and the final EIS (FEIS). The public responds to the draft, and those comments and concerns are addressed in the FEIS.

The EIS process begins with the lead agency, such as a state DOT, filing a notice of intent in the *Federal Register*, which describes the proposed action and scope. This invites public participation in defining the scope.

The EIS—draft or final—must describe indirect and cumulative effects, as well as direct effects from the project. Indirect effects include the growth-inducing effects of a project and related changes in land use, as well as changes in population density and long-term effects on air, water, and other natural resources.

As a general rule, a legally sufficient EIS will include (1) a purpose and need statement that clearly articulates the benefits arising from the project; (2) a description of the project and the area to be impacted; (3) a full discussion of the alternative routes or designs considered, including the no-build alternative, with explanations for the respective dismissals of the alternatives; (4) a description of all impacts—direct, indirect, and cumulative; (5) an account of public participation and coordination with appropriate resource agencies; (6) an evaluation of any issues raised by the public and the agencies, and (7) a discussion of measures taken to minimize or mitigate any adverse effects arising from the project. In the words of FHWA, the NEPA document must “adequately describe the reasons for a factual conclusion or decision on the issue and account for new information or circumstances.”

The lead agency sends copies of the DEIS to the EPA and “any federal agency that has jurisdiction by law or special expertise in respect to any environmental impact, or that is authorized to develop and enforce environmental standards.” Those agencies’ comments must be obtained. Comments are also requested from “appropriate state and local agencies authorized to develop and enforce environmental

standards; Indian tribes (when a reservation may be affected); ... and the public, especially persons or organizations that may be interested or affected.” The EPA then publishes a Notice of Availability of the DEIS in the *Federal Register*.

After receiving all comments, the EPA then reviews the DEIS and rates its environmental impact and adequacy of information. If the document is rated environmentally unsatisfactory, the EPA refers the document to the CEQ, which then attempts to resolve disputes between the lead agency and the EPA.

Upon completion of the public review and comments, the lead agency incorporates the comments into the FEIS. The FEIS is submitted for public review and submitted to the EPA (and CEQ) for review. The EPA then adds comments on the unresolved issues, if any, that arose during the review of the DEIS and notes any new significant impacts, if any, not previously discussed. The EPA then reviews the FEIS and issues a record of decision (ROD) in which it comments on the lead agency’s choice among the alternatives. The ROD becomes a public document published in the *Federal Register*.

Expediting the NEPA Process

For large and complex projects, the NEPA process can be rather time consuming and labor intensive. In response, there have been several efforts to expedite the process or make it more flexible. FHWA is actively promoting the expanded use of programmatic agreements (PAs), which are documents that spell out the terms of a formal, legally binding agreement between a state DOT and other state and/or federal agencies. With PAS, projects can be reviewed more quickly and project delivery time shortened.

To facilitate mitigation, states are now encouraged to create programs for wetland mitigation banking. There are several advantages to wetland mitigation banking, including ecological benefits for larger land areas, reduced reporting and monitoring time, and expedited processing and review of permits.

In the interest of clarifying the conditions under which a protected property could be used, Section 4(f) of the Department of Transportation Act of 1966, one of the most stringent of the environmental protection laws, was revised in 2008. Once there has been a determination that there is no prudent

alternative to the use of protected property, DOTs can now consider the costs of alternatives, as well as other factors (23 CFR—Part 774).

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See Also: Environmental Impacts; Environmental Protection Agency; Highway Planning.

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National Highway System Designation Act of 1995

When Congress passed the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the legislature instructed the Department of Transportation (DOT) to submit a proposal for a National Highway System (NHS) to Congress by September 1995. No funds were released for the project until Congress passed the National Highway System Designation Act of 1995 (S. 440), which President Bill Clinton signed into law (P.L. 104-59) on November 28, 1995.

The National Highway System Designation Act appropriated \$5.4 billion for highways and other transportation infrastructure projects. The chief purpose of the act was to determine which highways throughout the United States should be considered of "national significance" because of the

links they provided to other forms of transportation and to defense and military facilities. Even though those highways made up only 4 percent of the total number of U.S. highways, they handled 90 percent of all tourist traffic and 75 percent of all heavy-truck traffic on the nation's highways. (Designated roads in Puerto Rico were also included in the NHS.) Because 90 percent of the population live within roughly 5 miles of an NHS road, the entire country has become connected by the NHS.

Designating strategic highways as part of the NHS was also intended to provide cohesion to the transportation sector as a whole. In addition to linking key areas within the United States, the system provides 53 links to Canada and Mexico to facilitate the movement of goods across national borders. Another key element in the NHS Designation Act of 1995 was to improve highway safety throughout the United States.

National Highway System

In 1996, in the spring issue of *Public Roads*, which celebrated the NHS, Federal Highway Administrator Rodney Slater called the NHS the cornerstone of the effort to prepare the American transportation sector for the 21st century. As instructed by Congress in the Intermodal Surface Transportation Efficiency Act, officials from the Federal Highway Administration (FHWA) and the DOT worked closely with state and local governments and metropolitan planning organizations to identify roads within particular areas that should be included in the NHS.

While the interstate system accounts for some 30 percent of roads identified under the NHS Designation Act, most roads within the network are two-lane paved roads. Altogether, the NHS encompasses 161,000 miles of roads. According to the FHWA, the NHS is made up of five parts. The first of these is the Eisenhower Interstate System. The second section is comprised of high-priority corridors that were designated by the ISTEA. These roads serve as connectors, providing access to major transportation facilities such as ports and airports. The third section of NHS is comprised of approximately 61,000 miles of the Strategic Highway Network (STRAHNET), which is made up of strategically significant highways that are important to defense. A fourth section of the NHS is comprised of some 2,000 miles of connector roads that link major defense and military installations to STRAHNET. The final



A highway sign acknowledges the official designation of the interstate highway system as the Dwight D. Eisenhower National System of Interstate and Defense Highways. Eisenhower's role in the Federal Aid Highway Act of 1956 was crucial to the project.

section is comprised of all the roads that connect major intermodal facilities with the rest of the NHS. Taken as a whole, the NHS serves 198 ports, 207 airports, 67 Amtrak stations, 190 rail/truck terminals, 82 intercity bus terminals, 307 public transit stations, 37 ferry terminals, 58 pipeline terminals, and 20 multipassenger terminals.

Background

World War II hero General Dwight D. Eisenhower was elected president of the United States in 1952. In 1919, Eisenhower had participated in the War Department's Transcontinental Motor Convoy, which traversed the United States on two-lane roads that were in varying conditions of repair. With his military experience, Eisenhower was successful as president in pushing through the Federal Aid Highway Act of 1956, which established the interstate highway system in the United States. Congress was motivated by the need to emphasize defense and to

improve road travel during the Cold War, and the interstate system was officially designated as the Dwight D. Eisenhower National System of Interstate and Defense Highways. Although the system was set to be completed in 1969, it was another decade before it was finished. Delays were often caused by local officials vying to have their towns connected to the interstates, which were likely to bring tourists and much-needed revenue.

The interstate system used standardized design in order to enhance safety, functionality, and aesthetics. The standards were developed by state highway agencies working in conjunction with the American Association of State Highway and Transportation Officials (AASHTO). The design called for full control of access and the capability of handling speeds from 50 to 70 miles per hour. All roads were required to be at least two lanes in each direction, and it was stipulated that those lanes be 12 feet wide and contain a 10-foot right paved shoulder and a four-foot paved left shoulder.

In 1968, the Federal-Aid Highway Act expanded the interstate system to 42,500 miles and gave the secretary of transportation the authority to designate existing highways as part of the interstate system, as long as the roads met interstate standards. Five years later, the Federal Aid Highway Act of 1973 added another 500 miles to the system. Subsequently, the Surface Transportation Assistance Act of 1978 provided full funding for routes included in the interstate system, but ended funding for new interstate construction. The interstate system became an integral part of the NHS in the mid-1990s, and the standardization of roads enhanced their ability to facilitate movement during emergencies.

Provisions

In 1992, while campaigning for president, Bill Clinton and Al Gore, vice presidential candidate, crisscrossed America on buses. During that trip, Clinton first perceived the advantages of linking all highways in the nation through a national system. However, the bill that made it through Congress was not the bill that Clinton, as president, had sent to the legislature. When signing the bill, Clinton promised to keep working toward mitigating the impact of elements that had been removed from the bill.

Those key elements concerned the removal of a provision that would have forced states to enact

a national maximum speed limit, and toughened laws on the use of motorcycle helmets. The president's other concerns focused on exemptions that Congress had allowed for small-to-medium-sized trucks in the areas of driver qualifications and truck maintenance.

States were given considerable flexibility in using the funds appropriated by the bill, which removed existing requirements forcing states to comply with federal standards in building materials and program management. States were permitted to modify the map of designated highways within their boundaries, but only after submitting proposals for modifications to the secretary of transportation, who then submitted the proposed modifications to designated congressional committees for approval.

The Intermodal Surface Transportation Efficiency Act of 1991 had paved the way for the designation of four high-priority corridors as part of the interstate system, and Congress stipulated that all highways designated as Congressional High Priority Corridors under ISTEA be included in the NHS. The NHS Designation Act of 1995 also amended Section 1105 of ISTEA, which had divided surface transportation assistance funding among highways, bridges, railways, transit systems, bike paths, and walkways. In 1998, the Transportation Equity Act for the 21st Century modified the description of three of the four corridors and designated five additional corridors for future inclusion in the interstate program.

When debating passage of the NHS Designation Act, Congress was forced to contend with the fact that enactment of the ISTEA had reduced highway funding significantly. Because those reductions were estimated to amount to \$2.7 billion in 1996, the act sought to provide states with another means of obtaining federal funding for critical projects by allowing them to decide what their priorities should be.

Safety was a major element of the NHS Designation Act. The bill included a provision enacting the president's zero-tolerance policy toward young people driving under the influence of alcohol (DUI), which was designed to force states to exact tough penalties for DUI offenses by anyone under the age of 21 by withholding funds from states that refused to pass this legislation. In 1995, when the bill was passed, studies had shown that states with zero-tolerance laws were reporting 20 percent fewer

alcohol-related accidents than those states that did not have such laws.

Congress went against Clinton's attempts to make adopting the national maximum speed limit a requirement for receiving NHS funding, but it did require the secretary of transportation to submit a report detailing the human and economic costs to each state that chose to allow a maximum speed above the federal standard. The president also failed to convince Congress to maintain state laws mandating the wearing of motorcycle helmets by withholding federal funds from highway construction.

The NHS Designation Act authorized the \$2.55 million needed to extend the National Highway Traffic Safety Administration for an additional year. It also authorized a pilot program to exempt vehicles weighing between 10,000 pounds (4,500 kilograms) and 26,000 pounds (11,700 kilograms) from the Federal Motor Carrier Safety Regulations. Eligibility for the exemption was based on specific criteria and was dependent on maintaining an acceptable safety rating.

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See Also: American Association of State Highway and Transportation Officials; Federal Aid Highway Program; Federal Highway Administration; Federal Motor Carrier Safety Administration; Intermodal Surface Transportation Efficiency Act; Surface Transportation Assistance Acts of 1978 and 1982; U.S. Department of Transportation.

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National Highway Traffic Safety Administration

The National Highway Traffic Safety Administration (NHTSA) was established by the Highway Safety Act of 1970. Under the direction of the U.S. Department of Transportation, NHTSA's objective is to reduce deaths, accidents, and economic losses from motor vehicle collisions. One of the leading causes of death for 1- to 34-year-olds is vehicular crashes, with a loss of over 30,000 lives per year in the United States, a decrease from previous years. In 2009, 630 cyclists and 4,092 pedestrians were killed in traffic crashes within the United States, making pedestrian safety a focal concern of the NHTSA. In addition, there are 3.2 million crash-related injuries annually. Tasks of the NHTSA include the following:

- Investigate safety defects in motor vehicles
- Set and enforce fuel economy standards
- Help states and local communities reduce the threat of drunk drivers
- Promote the use of safety belts, child safety seats, and air bags
- Investigate odometer fraud
- Establish and enforce vehicle antitheft regulations
- Provide consumer information on motor vehicle safety topics

For 2014, NHTSA proposed a budget of \$828.3 million to address roadway safety, which is comprised of \$561.5 million for state grants and high visibility enforcement support, \$148.3 million for vehicle safety, and \$118.5 million for behavioral safety. This is \$26.8 million higher than the 2013 budget. Funding for Highway Safety Research and Development and Highway Traffic Safety Grants is mandatory, attributed to the Transportation Trust Fund (TTF). Because Vehicle Safety Research funding and spending is attributed to the General Fund (GF), it is discretionary.

Behavioral Safety

The NHTSA expenditures on behavioral safety focus on impaired driving and occupant safety. Through initiatives in education, in conjunction with law enforcement, the NHTSA has shown marked decreases in injuries and deaths. By seeking to sustain participation with criminal justice agencies, the NHTSA supports the Data-Driven Approaches to Crime and Traffic Safety (DDACTS) program, conducted in partnership with the Department of Justice. The NHTSA also plans to contribute to the National Drug Control Strategy program produced by the Office of National Drug Control Policy.

The Click It or Ticket (CIOT) campaign is a broad-scale approach to increase seatbelt use, and to further enhance the biannual (Labor Day and December) anti-distracted-driving campaigns. Eighteen percent of vehicular crashes in 2010 were caused by distraction-related incidents. Drivers who were text-messaging while driving were 27.7 times more likely to be involved in an accident. This is particularly significant when compared with other activities. For example, drivers who were reading a book or newspaper while driving were only 4.8 times more likely to be involved in an accident.

Reductions in pedestrian crashes, which disproportionately affect children, older adults, and Hispanics, are targeted through behavioral initiatives, including education and law enforcement. The NHTSA has supported "Pedestrian Focus Cities" and "Focus States" with the education and enforcement components of its Pedestrian Safety Action Plans. These initiatives have led to a decrease in pedestrian-related incidents. While efforts have been focused particularly in Florida, New Mexico, North Carolina, and the city of Chicago, the NHTSA will continue to conduct demonstrations

to help law enforcement agencies implement the “Standardized Pedestrian Crosswalk Enforcement” program and other components of the Pedestrian Safety Action Plan.

Research

The NHTSA focus on vehicle safety centers around research. Critical research areas include vehicle structure and restraints, human biomechanics, crash avoidance and human factors, heavy vehicle safety, alternative-fuel vehicle safety, and connected vehicle research.

Much of the NHTSA research on structure and restraints focuses on the use of hydrogen fuel. Examples of recent studies include an analysis of hydrogen vehicle safety, fuel system life cycles and durability, and fire safety research regarding both localized and post-crash leakage.

A significant amount of current research is devoted to crash avoidance and the human aspects of transportation. Examples of current, ongoing studies by the NHTSA in the category of crash avoidance, human biomechanics, and human factors research include the following: biomechanical investigations using human surrogates; brain injury criteria for 6- to 10-year-old children; development of advanced instrumentation, test procedures, injury criteria, and injury analysis software for crash test analysis that can be used for all individual injury modes; and distraction detection and mitigation through driver feedback.

While not a significant focus of current research efforts, NHTSA's heavy vehicle safety research includes commercial vehicle rollover prevention technology and hardware-in-the loop analysis for heavy truck electronic stability control (ESC).

Alternative Fuel Vehicle Safety/ Corporate Average Fuel Economy (CAFE)

The purpose of CAFE is to reduce energy consumption through enhanced fuel economy of cars and light trucks. Joint Final Rules for Corporate Average Fuel Economy and Greenhouse Gas Emissions regulations for model years beginning in 2017 are recent standards set by the NHTSA in coordination with the Environmental Protection Agency (EPA). These regulations aim to help address U.S. dependence on imported oil, save consumers money at the pump, and reduce emissions of greenhouse gases that contribute to global climate change.

State Grants and Enforcement Support

For 2014, the NHTSA requested funding for a new incentive grant program to encourage states to enact laws that prevent distracted driving, such as the following:

- Laws restricting cellular phone use and texting while driving
- State graduated driver licensing laws programs, including a two-stage licensing process for young drivers
- An In-Vehicle Alcohol Detection Device Research program, which supports discretionary research on in-vehicle technologies designed to prevent alcohol-impaired driving

In addition to support of new initiatives, the NHTSA continues to support existing state grants and high-visibility enforcement in such areas as child safety and booster seat incentives, impaired driving countermeasures, motorcyclist safety, occupant protection incentives, and state traffic safety information system improvements, as well as funding NHTSA's annual media campaigns.

The U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) has a broad and far-reaching objective to reduce deaths, accidents, and economic losses from motor vehicle collisions. Through its work in research, behavioral safety, state grants, and high-visibility enforcement support, the NHTSA has been effective in reducing the number of deaths, injuries, and economic costs associated with the ever growing transportation system in the United States.

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See Also: Accident Avoidance Systems; Alternative Automotive Fuels; Automobile Accidents and Prevention; Collision Avoidance Systems, Automobile; Automobile Safety Inspections and Registration; Automobile Safety Systems; Distracted Driving; Pedestrian Safety; Vehicle Emissions Standards.

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- The use of the transportation system by demographic groups to determine mobility barriers, the rate of accidents and fatalities (exposure and risk analysis), and travel demand
- Development of performance measures to evaluate system stresses, such as congestion measures
- Evaluation of potential planning and policy initiatives
- Travel behavior benchmarks for local and regional planning agencies
- The public’s view of the adequacy of transportation systems and services

National Household Travel Survey

Since 1969, the National Household Travel Survey (NHTS), previously known as the Nationwide Personal Transportation Survey (NPTS), has been an established U.S. Department of Transportation (DOT) program. The NHTS is the DOT’s only inventory of passenger travel. The data are used to determine current travel characteristics, such as the relative proportion of travel by mode (for example, vehicle, transit, and walk) and purpose (for example, work, school, family/personal, and recreation) by residents of U.S. households. These data allow the DOT to evaluate the adequacy of existing transportation facilities and estimate future needs. The NHTS is consolidated with other data to provide a biannual report to Congress. The major portion of funding for the survey has come from the Federal Highway Administration, but in 2001 the Bureau of Transportation Statistics contributed a significant amount along with other DOT agencies.

In addition, data from the NHTS serves to answer important questions from the secretary of transportation’s office, Congress, state and local departments of transportation, researchers, and the media on current characteristics of travel by the American public, including the following:

- Factors that affect the use of private vehicles, carpooling, and alternative modes

Seven national travel surveys have been conducted in the following years: 1969, 1977, 1983, 1990, 1995, 2001, and 2009. The NHTS is the only national authoritative source to obtain current information on national patterns of travel to better understand travel behavior, evaluate the use of transportation facilities, and gauge the impact of the department’s policies and programs. It helps measure the performance of the surface transportation systems in the United States, including the efficiency, safety, energy use, air quality, congestion, active health measures, and intermodal transportation systems. It serves transportation researchers, planners, and policy makers with comprehensive data on travel and transportation patterns in the United States.

Data Collected

The 2009 NHTS provides information to assist transportation planners and policy makers who need comprehensive data on travel and transportation patterns in the United States. The NHTS/NPTS serves as the nation’s inventory of daily travel. Data is collected on daily trips taken in a 24-hour period and includes the following:

- Purpose of the trip (work, shopping, etc.)
- Means of transportation used (car, bus, subway, walk, etc.)
- How long the trip took, that is, travel time
- Time of day when the trip took place
- Day of week when the trip took place
- Number of people in the vehicle (vehicle occupancy); driver characteristics (age, sex, worker status, education level, etc.) and vehicle attributes (make, model, model

year, amount of miles driven in a year) for private vehicle trips

These data are collected for all trips, modes, purposes, trip lengths, and areas of the country, including both urban and rural.

Uses and Scope of NHTS

NHTS data are used to quantify travel behavior, analyze changes in travel characteristics over time, relate travel behavior to the demographics of the traveler, and study the relationship of demographics and travel over time.

The NHTS data are used primarily for gaining a better understanding of travel behavior. The data enable DOT officials to assess program initiatives, review programs and policies, study current mobility issues, and plan for the future. It has also been a tool in the urban transportation planning process because it provides personal travel behavior trends, trends in travel over time, trip generation rates used to benchmark when comparing local data, and data for various other planning and modeling applications.

The transportation research community, including academics, consultants, and government, use the NHTS extensively to examine travel behavior at the individual and household level; the characteristics of travel, such as trip chaining, use of the various modes, amount and purpose of travel by time of day and day of week, vehicle occupancy, and a host of other attributes; the relationship between demographics and travel; and the public's perceptions of the transportation system.

People in various fields outside transportation use the NHTS data to connect the role of transportation with other aspects of life. Medical researchers use the data to determine crash exposure rates of drivers and passengers, including the elderly, who have heightened morbidity and mortality rates. Safety specialists study the accident risk of school-age children, particularly when they are traveling on their own by walking or biking. Social service agencies need to know more about how low-income households currently meet their travel needs.

The scope of the 2009 NHTS data set includes, but is not limited to, the following:

- Household data on the relationship of household members, education level,

income, housing characteristics, and other demographic information

- Information on each household vehicle, including year, make, model, and estimates of annual miles traveled
- Data about drivers, including information on travel as part of work
- Data about one-way trips taken during a designated 24-hour period (the household's travel day), including the time the trip began and ended, length of the trip, composition of the travel party, mode of transportation, purpose of the trip, and the specific vehicle used (if a household vehicle)
- Information to describe characteristics of the geographic area in which the sample household and workplace of sample persons are located
- Data on telecommuting
- Public perceptions of the transportation system
- Data on Internet usage
- Typical number of transit, walk, and bike trips made over a period longer than the 24-hour travel day

In the past, there have been many requests for data that are closely related to but are not available in the survey. Examples of the most common requests for data that are not included in NHTS are the following:

- Information on costs of travel
- Information about specific travel routes or types of roads used
- Travel of the sampled household changes over time
- Information that would identify the exact household or workplace location
- The traveler's reason for selecting a specific mode of travel over another mode

Add-On Samples

A key function of the NHTS has been the inclusion of an add-on program, in which states and metropolitan planning organizations have the unique opportunity to purchase additional samples for their jurisdiction through a pool funding mechanism operated by the Federal Highway Administration. These additional samples, along with random

national samples collected in the add-on area, are compiled into a cleaned geocoded database for ready application to local planning and forecasting. Trips of all lengths, for all purposes, and for all modes are collected.

The add-on program started with five state and metropolitan planning organizations in 1985 and grew to 20 members in 2009. In 2009, it provided one of the largest household sample sizes of over 151,000 household interviews with over 320,000 individual interviews that represented all 50 states.

Design, Implementation, and Sample

In general, the survey designs have changed over the years, starting with face to face in 1969 and 1977 and then switching to telephone. In 2001 it was a list-assisted random digit dialing (RDD) computer-assisted telephone interviewing (CATI) survey conducted over an entire year. Eligible households were in the civilian, noninstitutional, and noninstitutionalized population of the United States. People living in medical institutions, prisons, and in barracks on military bases were excluded from the sample.

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See Also: Transportation Surveys; Travel by Households; Travel by Persons; Travel Choice; Travel Demand; Travel Demand Forecasting; Travel Destinations; Travel Patterns by Income; Travel Patterns by Race/Ethnicity; Travel Patterns of the Elderly; Travel Patterns of Women; Travel Surveys.

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National Mass Transportation Assistance Legislation

In the mid-1970s, the ever increasing number of fossil-fuel-burning vehicles on U.S. roads was not only leading to intense traffic congestion in many cities but was also generating concerns about the damage that those fuels exerted on the environment. Consequently, mass transit began to receive greater attention.

In 1974, Congress enacted the National Mass Transportation Assistance Act (P.L. 93-503), which authorized \$11.8 billion in federal funds for mass transit projects. It was the first time that federal funds had been designated for assisting individual states and cities in meeting operating expenses for mass transit systems. The bill also earmarked funding for public transportation in rural areas.

President Gerald Ford signed the bill into law on November 26, 1974. During the signing ceremony, Ford acknowledged that passage of the bill had not always run smoothly, but he praised members of Congress for working together to reconcile the many differences that had surfaced during the course of the bill's becoming law. In 1978, Congress worked with the administration of President Jimmy Carter to extend funding for assistance to mass transit. In 1982, under President Ronald Reagan, the administration failed to win support in its attempts to drastically slash mass transit assistance, but it did manage to redesign the formula for receiving assistance with the Federal Public Transportation Act of 1982.

Earlier Federal Actions

Because funds were lacking during the Great Depression and gasoline rationing placed additional pressure on mass transit during World War II, most U.S. transit systems were in serious need of repair by the 1950s. Many companies faced bankruptcy.

In 1961, Congress made its first move toward restoring mass transit by providing funding for commuter railroads in the Housing Act. By 1962, politicians and the general public were coming to see the need for federal assistance for the mass transportation sector. That year, in a speech to Congress, President John F. Kennedy urged the national legislature to pass new transportation legislation to

assist cities and regions in expanding access to mass transit. Such a move, he insisted, was necessary for promoting urban renewal.

It was not until two years later, however, that Congress passed the Urban Mass Transportation Act of 1964 as part of President Lyndon Johnson's Great Society reforms. The 1964 act established a 12-year, \$375 million program of grants and loans, which was designed to fund the improvement and expansion of mass transit programs. This was a major victory for the transportation sector.

The federal grant program established in the bill provided assistance of up to two-thirds of the capital costs involved in constructing and acquiring facilities and in purchasing equipment. The rationale behind the act was that the influx of federal funds would spur local investors to supply the remaining one-third needed to create and improve mass transit systems. Studies that examined the growth of mass transit in the period following the act's passage indicated that the number of publicly owned transit systems grew from 58 in 1965 to 308 in 1974.

The 1964 act also established the Urban Mass Transportation Administration (UMTA) under the auspices of the U.S. Department of Transportation. In its early days, one of UMTA's major functions was to help cities buy bus companies that were failing, thereby ensuring that mode of public transportation survived. Within five years of the passage of the act, only \$700 million in federal money had been used to fund 148 mass transit projects. In the Urban Mass Transportation Assistance Act of 1970, Congress broadened the scope within which federal funds could be used.

Mass Transportation Assistance Acts of 1974 and 1978

When Congress addressed the issue of federal aid to mass transit within the context of the National Mass Transportation Assistance Act of 1974 (P.L. 93-503), the United States was experiencing a trend toward revenue sharing according to designated mathematical formulas. Members of Congress from rural areas, who dominated a number of congressional committees, opposed the measure because they were extremely reluctant to direct large chunks of federal funds to urban areas. As a compromise measure, the bill set aside funds that could be used for either operating costs or for capital expenses.

Half of federal funds received under the provisions of the act could be used to defray operating expenses. However, access to those funds was limited by Section 5, which stipulated that funds be allotted according to population. In areas with populations greater than 200,000, funds were given directly to the recipient. States were assigned responsibility for dispensing funds to areas with populations between 50,000 and 200,000. Ultimately, approximately 87 percent of funds dedicated to mass transit grants under the 1974 act were used for operating expenses. The 1974 act also granted new concessions to the elderly and the disabled by requiring that they be charged half-fares on mass transit systems when traveling during nonpeak time periods.

Since the 1974 bill had funded mass transit assistance through 1979, Congress was again set to consider new policy on the issue as the decade drew to a close. By 1977, when Secretary of Transportation Brock Adams began working with key senators to develop a funding plan that met the requirements of the Carter administration without causing major upheaval, large cities such as New York and Washington, D.C., already had a backlog of projects because of a lack of funds. The Senate plan called for a \$5.7 billion appropriation to fund assistance to mass transit for the following five years. While that funding was considered a victory in light of Adams's earlier insistence that no new funds were needed for mass transit assistance, it was considerably less than the \$11.4 billion called for in a bill sponsored by Senator Harrison A. Williams (D-NJ).

The 1978 bill extended the reach of the National Mass Transportation Assistance Act by allowing recipients of mass transit assistance to use such funds for capital expenses and for operating fixed-rail projects. The 1978 Federal Public Transportation Act, Title III of the Surface Transportation Assistance Act of 1978 (P.L. 93-599), also created metropolitan planning organizations (MPOs). Bowing to pressure from large cities that argued that the formula used in assistance grants should be based on the scope of transit services rather than on population, the 1978 bill initially provided a compromise, establishing a tier system for grants allotted under Section 5. One tier granted 85 percent of federal mass transit funds to cities with populations of more than 750,000. Another tier earmarked funding for cities with subways. An additional tier protected the needs of smaller

cities by funding the purchases of buses to be used for public transportation. Transportation Secretary Neil E. Goldschmidt suggested abolishing the proposed tier system, and the Senate complied, delighting urban lobbying groups.

The 1982 Bill and Beyond

In 1982, the United States was experiencing a major economic recession and one of Reagan's suggested cutbacks was to eliminate all federal assistance geared toward operating mass transit programs. In response to intense controversy, Reagan agreed to support funding through block grants as part of the Federal Public Transportation Act of 1982, Title III of the Surface Transportation Act of 1982 (P.L. 94-424). However, the Reagan administration insisted on the provision that federal assistance be capped at 80 to 95 percent of previous levels. The 1982 act also established a one-cent tax on each gallon of gas purchased at the pump. Funds from the tax were placed in the Highway Trust Fund to cover the grant program.

Five years later, Congress overrode a presidential veto of the Federal Mass Transportation Act of 1987 (P.L. 100-17) to increase the federal-assistance caps by 32.3 percent for cities with populations over 200,000. At that time, Congress allotted 40 percent of grant funds to constructing and extending transit lines, 40 percent to modernization programs, and 10 percent to funding major bus projects. The final 10 percent was dedicated to a discretionary grant program. A subsequent bill, the Federal Transit Act Amendments, passed in 1991 as part of the Intermodal Surface Transportation Efficiency Act of 1991 (P.L. 102-240), shifted the discretionary fund allotment to bus projects.

1998 Amendments

In 1998, the Federal Transit Act, Title III of the Transportation Equity Act for the 21st Century (P.L. 105-178), provided an additional \$41 billion in federal funding for mass transit. Even though federal assistance to mass transit increased during the 1990s, state and local governments began to take on more responsibility for their own systems, contributing some 60 percent of funds spent on mass transit during the decade. Together, the Intermodal Surface Transportation Efficiency Act of 1991 and the Transportation Equity Act for the 21st Century, enacted in 1998, promoted greater flexibility

in using federal funds for meeting individual transportation needs in states and cities, with funds able to be divided between highways and mass transit.

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See Also: Highway Trust Fund; Intermodal Surface Transportation Efficiency Act; Subway Systems; Transit Finance; Transit Industry, Economics of; Transportation Equity Act for the Twenty-First Century; Transportation Planning; Urban Mass Transit Act of 1964; Urban Mass Transportation Assistance Act of 1970.

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National Railroad Passenger Corporation/Amtrak

The National Railroad Passenger Corporation is better known as Amtrak, a name that is derived from

the words *America* and *track*. Amtrak was created as a federally subsidized mass transit system.

While most large cities provide mass transit through local or regional systems, Amtrak has historically been the only system that connects geographically distant cities. Amtrak works closely with passenger lines owned by states, such as the Virginia Railway Express, and by regions, such as the Massachusetts Bay Transportation Authority. In 2012, some 28 million passengers used the 300 trains operated by Amtrak that ran on 21,000 miles of track. Forty-six of the 50 states, as well as Washington, D.C., and parts of Canada, are currently connected by Amtrak. Only Alaska, Hawai'i, South Dakota, and Wyoming are not part of Amtrak's route.

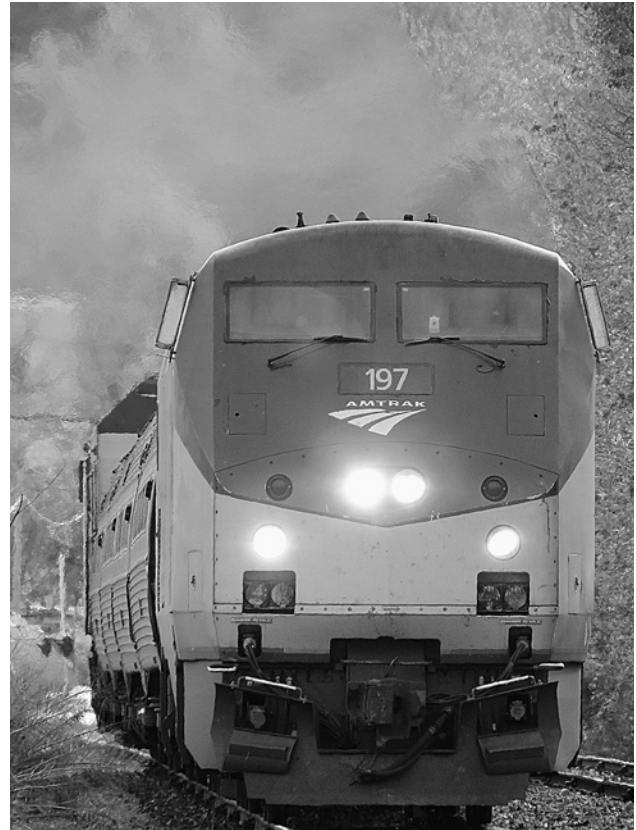
The most widely used network within Amtrak, which transports some 300,000 passengers each day, is the Northeast Corridor, covering 450 miles and connecting cities including New York, Boston, and Washington, D.C. While Amtrak has consistently delivered on its promise of preserving passenger trains, the company has not always been financially stable. Between 1971 and 2002, Amtrak received an average of \$760 million a year in government subsidies, amounting to a total of \$25 billion. Even so, government funding for Amtrak has been considerably less than amounts spent on supporting highways and aviation during that same period.

Preserving Passenger Railways

Despite the importance of railroads to the founding of the United States and the essential role they played in the Industrial Revolution, the increase in automobile ownership and the creation of a national highway system, coupled with the rise in air travel, meant that the need for passenger railroads began to diminish over the course of the first half of the 20th century.

Passenger trains had virtually disappeared in the United States by the 1960s. In an effort to save them, officials began pressuring President Richard Nixon to agree to government subsidies of private railways, but Nixon was reluctant to commit to that action. Instead, Congress passed the Rail Passenger Service Act of 1970, which established the National Railroad Passenger Corporation (Amtrak) as a quasi-public passenger rail system.

Amtrak initiated operations on May 1, 1971, and the first train left Pennsylvania Station in New York City on its way to Philadelphia. Amtrak operated 184



An Amtrak Downeaster route train in Wakefield, Massachusetts, in November 2012. Amtrak's Northeast Corridor serves as many as 300,000 people every day on the railways between Washington, D.C., and Boston, Massachusetts.

trains in that first day in business. Initially, Amtrak's train stock was highly diverse. Railroad historians and train buffs dubbed the period "the Rainbow Era" because most of Amtrak's cars had been purchased from other companies. It took three years; but in 1974, Amtrak introduced the red, white, and blue color scheme that became familiar in many cities throughout the United States.

In 1972, Amtrak's service was extended to Canada, connecting designated American cities with Vancouver, British Columbia, and Montreal, Quebec. The following year, the Regional Rail Reorganization Act transferred service for the Northeast Corridor to Amtrak. In 1978, Congress passed the Amtrak Improvement Act, and the administration of President Jimmy Carter began looking into ways to make Amtrak more profitable.

When Conrail, the government-subsidized freight railway service, ran into major financial problems in

the early 1980s, officials were forced to turn their short-haul commuter operations over to Amtrak under the auspices of the newly created Amtrak Commuter Services Corporation. By 1981, Amtrak had placed 1,436 new or rebuilt electric railcars into operation. In 1992, for the first time, commuters comprised the largest segment of Amtrak's passengers, and six years later, the company recorded passenger-generated revenues of more than \$1 billion.

Disaster and Recovery

Throughout the 1980s and 1990s, Amtrak borrowed money from private lenders, paying it back out of government subsidies. In 1996 and 1997, Amtrak reported overall losses of \$764 million and \$762 million, respectively, and began scaling back its operations. Congress responded by passing the Amtrak Reform and Accountability Act of 1997, which mandated self-sufficiency. Amtrak officials reacted by proposing that the company be split into two entities, separating Northeast Corridor operations from all others.

In 2000, high-speed rail (HSR) was introduced to Amtrak's Northeast Corridor. Powered by electricity, these trains were capable of speeds up to 150 miles per hour, which significantly cut down commuting time. Thus, it was possible to travel between Washington, D.C., and New York City in 2 hours and 45 minutes. Many railway enthusiasts saw HSR as a way to save passenger rail service in the United States, and they wanted to expand its use throughout Amtrak's networks. One of their strongest arguments was the potential role that HSR could play in protecting the environment. The Environmental Law and Policy Center reported that HSR is three times more fuel efficient than automobiles and six times more fuel efficient than airplanes. Thirty-four states invested \$1 billion in building 10 HSR corridors.

The period following the terrorist attacks of September 11, 2001, saw a brief rise in Amtrak's passenger count as fear of air travel became common. By 2002, Amtrak was operating 265 trains per day, and 23.5 million passengers per year were traveling along the 23,000 miles that made up Amtrak routes in 500 cities.

However, problems arose as a result of several accidents that occurred that year. The first occurred in Crescent City, Florida, on April 18, when two railcars derailed as a result of a perceived

track misalignment, killing four passengers and injuring 150 others. On July 20, a train traveling from Chicago to Washington, D.C., derailed in Maryland following a heat-induced track misalignment, injuring more than 100 passengers. Then, on August 21, a third derailment occurred in San Jose, California, when an Amtrak train struck a piece of metal deposited on the track by a freight train, resulting in seven injuries. All of these incidents damaged both railcars and tracks, and Amtrak's situation became more dire after it was discovered that tracks between Washington, D.C., and Boston had cracks.

The very existence of Amtrak began to be hotly debated. Supporters maintained that mass transit was essential to reducing global warming, cutting down on highway congestion, and curtailing urban sprawl. They also argued that it served as an economic stimulant by spurring growth in urban areas. Those on the other side of the argument contended that rail travel in the United States should be relegated to history, and they strenuously objected to billions of federal dollars being poured into subsidizing Amtrak. It was a crucial point in Amtrak's history because the company was on the brink of financial collapse. In order to stave off bankruptcy, supporters convinced President George W. Bush to release \$100 million in emergency loans, and Congress approved an additional \$205 million.

By 2006, Amtrak was on the road to recovery, reporting record revenues in November. In 2008, Congress passed the Passenger Rail Investment and Improvement Act, reauthorizing Amtrak and paving the way for additional improvements to the system. In 2009, under President Barack Obama's American Recovery and Reinvestment Act, Amtrak received \$1.3 billion to improve operations further, and another \$8 billion was set aside for working with states to develop intercity and high-speed rail networks. In 2011, Amtrak received a \$562.9 million loan from the Federal Railroad Administration for the purchase of 70 new energy-efficient and high-performing electric locomotives, representing an important step toward Amtrak's future as an efficient, environmentally sustainable, and desirable means of mass transportation.

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See Also: Consolidated Rail Corporation; National Mass Transportation Assistance Legislation; Rail Transit Planning, U.S.; Railroads, Passenger; Trains.

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National Transportation Safety Board

The U.S. Congress established the National Transportation Safety Board (NTSB) in 1967 in order to streamline and improve government safety oversight of the transportation system. The NTSB's main function is the investigation of transportation accidents within its jurisdiction and the issuance of safety recommendations. Aircraft accident investigations are one of the NTSB's primary and most public functions. Aircraft accidents received heightened media attention after World War II as skies became more congested, passenger loads increased, and accidents involved larger commercial aircraft and claimed larger numbers of victims.

The NTSB is only authorized to investigate aviation accidents within U.S. territory or in international waters, but it often sends representatives to

assist foreign government investigations of overseas accidents involving U.S.-based air carriers or aircraft manufactured within the United States, which represents much of the world's carrier fleets.

NTSB accident investigations encompass a variety of civil transportation modes, including aviation, highway, marine, pipeline, and railroad. The agency also investigates accidents related to hazardous material transportation. NTSB statistics list annual agency investigation rates at approximately 2,000 aviation incidents and accidents, as well as approximately 500 accidents involving other modes of transportation. Historical statistics list over 130,000 aviation accidents and thousands of surface transportation accidents investigated, along with the issuance of over 13,000 safety recommendations.

On-call expert "Go Teams" form the core of NTSB accident investigation, issuing accident reports and safety recommendations. A five-member board oversees the NTSB and finalizes accident reports. The NTSB has no regulatory or enforcement authority, but it coordinates federal, state, local, and voluntary agency and air-carrier disaster response resources for major airline accidents, as required by the 1996 Aviation Disaster Family Assistance Act. The NTSB performs the same function for major rail passenger accidents involving Amtrak under the Rail Passenger Disaster Family Assistance Act of 2008.

Formal federal aviation accident investigation within the United States originated in the U.S. Department of Commerce under the Air Commerce Act of 1926. The Civil Aeronautics Board Bureau of Aviation Safety assumed responsibility in 1940, serving until Congress established the NTSB as part of the U.S. Department of Transportation (DOT) in 1967. The NTSB was originally housed under the DOT, replacing the older, disjointed, and less effective system where individual agencies separately handled different aspects of the same accident investigation relevant to their jurisdiction or expertise.

Congress designated NTSB independent of the DOT in 1975, under the Independent Safety Board Act of 1974, to strengthen its investigatory capabilities and remove potential conflicts of interest. The federal government further enhanced NTSB objectivity by preventing its involvement in the regulation, enforcement, funding, and direct



A member of a National Transportation Safety Board team inspecting the wreckage of a train car in the aftermath of a derailment in Fairfield, Connecticut, in May 2013.

operation of any of the transportation modes within its oversight.

The five NTSB board members are appointed by the president and serve five-year terms. The president designates two board members as chairman and vice chairman for two-year terms. The Senate must approve the board members, as well as the selection of chairman. The agency houses the following departments: chief financial officer; general counsel; managing director; communications; equal employment opportunity; diversity and inclusion; research and engineering; railroad, pipeline, and hazardous materials investigations; aviation safety; highway safety; marine safety; chief information officer; administration; and administrative law judges. The NTSB comprised approximately 400 employees in 2013.

The NTSB has operated the NTSB Training Center (originally known as the NTSB Academy) within the Ashburn, Virginia, campus of the George Washington University since 2003. The center provides internal employee training and offers transportation disaster response training courses for outside groups, such as emergency responders and local

and state agencies, as part of its mission to improve the coordination of federal, state, and local government resources.

The NTSB's administrative law judges hear appeals to the board from airmen, mechanics, or mariners of certificate actions by the Federal Aviation Administration (FAA) or U.S. Coast Guard Commandant. There are four judges—two based in Washington, D.C.; one based in Arlington, Texas; and one based in Denver, Colorado. The NTSB board members review appeals of the administrative law judges' case decisions.

Accident Investigations

NTSB investigations are centered on a rotational system of Go Teams comprised of various-sized groups of NTSB employees. Go Team members are specialists in fields related to the mode of transportation involved in the accident under investigation. Go Teams are designed for both quick response and a broad array of expertise, both critical factors in successful accident investigations.

The NTSB designates appropriate outside companies or organizations as parties to each investigation. The Federal Aviation Administration (FAA) is automatically designated as a party under the law. Non-NTSB representatives work under the appropriate Go Team specialist and report directly to the NTSB. The party system is cost-effective and allows the NTSB to utilize outside expertise and resources. If criminal activity is determined during the course of the investigation, the NTSB turns lead status in the investigation over to other federal agencies, such as the Federal Bureau of Investigation (FBI), but will remain involved in a supporting role if requested to do so.

A senior-level person, known as Investigator in Charge, coordinates the overall investigation, while each specialist oversees a working group that includes representatives from the relevant outside parties. Various groups within the Go Team remain on site as long as necessary and will travel to other sites deemed relevant to the investigation, such as an aircraft manufacturing plant or maintenance facility.

Aviation accidents tend to have larger investigative teams than accidents involving surface modes of transportation. Aviation specialties may include operations, structures, power plants, systems, air traffic control, weather, human performance,

survival factors, aircraft performance, maintenance records, and eye witnesses. Teams responsible for flight-data and cockpit-voice-recorder analysis meet at the NTSB's Washington, D.C., headquarters, where they are later joined by other team members as their field investigations conclude.

Go Teams are accompanied by an NTSB board member and a public affairs officer, both of whom handle media contact. NTSB policy dictates the release of only factual information and/or safety recommendations to the media and public during the course of an investigation. There is no speculation given as to the causes of an accident. Public hearings involving witness testimony given under oath could be part of major accident investigations.

Publications

The NTSB generates accident reports at the conclusion of each accident investigation. Accident reports encompass detailed factual data and information, as well as analysis and conclusions, including probable accident causation and relevant safety recommendations to prevent similar future accidents. Draft accident reports originate within the Go Team assigned to a particular accident, and board members are responsible for the final report.

The designated chairperson of each investigative group within the Go Team ultimately submits a report on the group's aspect of the accident investigation, which then goes to other groups for verification before becoming part of the public record. Designated outside parties who have assisted in the investigation can also submit their findings for the public record, but they do not aid in NTSB final analysis or reporting. The board prepares the final draft of the accident report and deliberates its findings in a public board meeting. The final report is then published and uploaded to the NTSB Web site.

The NTSB also generates safety recommendations and reports. These could be a result of specific accident investigations or a result of broader safety studies or special investigations conducted separately from accident investigations. The NTSB often issues safety recommendations while an investigation is still active because of the timely importance of safety and the prevention of future accidents. Safety recommendations and reports are placed on the NTSB Web site and are also sent

to any company or agency deemed relevant to the implementation of such recommendations.

Databases

The NTSB and its Web site maintain a number of searchable databases, including its Docket Management System, Aviation Accidents, Safety Recommendation Query, Foreign Investigations, and NTSB Case Decisions database. NTSB reports cover the fields of aviation, highway, marine, pipeline, hazardous materials, and railroad. The NTSB also maintains a "most wanted list" of its top advocacy priorities for enhancing transportation safety. Public safety alerts share designated safety information with the public and encourage citizens to contact state lawmakers regarding these issues.

Regulations governing legal use of reported NTSB findings were put in place to maintain focus on the agency's paramount mission of transportation safety and to avoid any undue influence or conflict of interest. The analysis of data and determination of an accident's probable cause are not admissible as evidence in a court; designated outside investigation team members are not allowed to be put in legal or litigation positions, and limitations are placed on the types of information NTSB employees may testify to in a court case.

Transportation Disaster Assistance Division

Media attention and resulting public criticism over the lack of coordination between the airlines and various agencies involved in large accidents in the past led to the passage of the 1996 Aviation Disaster Family Assistance Act, later followed by the Rail Passenger Disaster Family Assistance Act of 2008. Under these laws, the NTSB is mandated to coordinate federal, state, local, and voluntary agency disaster response resources for major air carrier accidents within the United States and major rail passenger accidents involving Amtrak.

The Aviation Disaster Family Assistance Act covers all commercial aviation accidents involving specified levels of mass fatalities, whether domestic or foreign, within the United States, as well as its territories, possessions, and territorial seas. The NTSB will provide similar coordination for general aviation accidents and accidents involving other modes of transportation upon request, although the agency is not required to provide such services. The NTSB is also not required to provide family

assistance to U.S. citizens involved in overseas aviation accidents.

The NTSB coordinates efforts with the Department of State, Department of Health and Human Services, FBI, Department of Homeland Security, and Department of Defense, as well as the American Red Cross. The Transportation Disaster Assistance Division (TDA) performs this part of the NTSB's mission. Assistance covers a variety of services, including facilitating the availability of information and federal resources to state, local, and voluntary authorities and airlines. The TDA will also share its disaster family assistance knowledge with the transportation industry, as well as both domestic and foreign government agencies upon request.

Service coordination may include such areas as information dissemination, family counseling and crisis counseling support, victim identification and forensic services, personal effects management, memorial services, communication with foreign governments, and translation services. The TDA also manages the Family Assistance Center (FAC), a central space for meeting and service provision for survivors and victims' families typically established by the air carrier involved in the accident under investigation.

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See Also: Airplane Disasters; Collision Avoidance Systems, Airplane; Federal Aviation Administration; Federal Railroad Administration; Hazardous Materials Transport; National Railroad Passenger Corporation/Amtrak; Railroads, Passenger; Security, Transportation; Terrorism, Transportation Systems as Targets of.

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Neighborhood Disruption From Highway and Transit Construction and Operations

“Neighborhood disruption” is a broad term most commonly used in transport planning to refer to the various types of economic, social, and environmental disadvantages experienced by a community arising from the implementation of transport projects. Neighborhood disruption is a form of externality. That is, the benefits gained from the transport project are not necessarily shared equitably with the community that experiences disruption related to the transport project. For example, transport projects that are aimed at improving travel times on the transport network could require the bypassing of communities to provide more efficient routes for those traveling.

Changing transport infrastructure inevitably results in a certain level of disruption to neighborhoods. Land use may change. Residents and businesses may be forced to relocate. Travel behavior choices may become restricted or less favorable. The construction process can degrade the neighborhood environment, as well as become a source of inconvenience and disadvantage to those directly impacted. The new infrastructure may act as a barrier restricting previous patterns of movement between people and places.

Although it is unrealistic to expect the elimination of disruption effects from transportation projects, there is also value in trying to understand the community's disruption concerns. Failure to address those concerns can give rise to community resistance to the transport project, which can delay or, worse, threaten the completion of good transport projects.

Neighborhood disruption is not confined to the construction of transport infrastructure but also includes the implementation of transport interventions. Transport interventions such as demand management strategies that change the price, priority, information, or access of transport options have the potential to disrupt individual travel preferences. Increasingly, the disruptive effects of transport interventions are used as an opportunity to

reduce car-dependent travel behavior and encourage use of more sustainable modes of travel. In such cases, the neighborhood disruption might have a greater effect on those who rely on being accessible by vehicle than the people wanting to travel on the new system.

In the context of sustainability, framing neighborhood disruption as a problem per se ignores the fact that disruption events are also desirable preconditions for changing the status quo. Disruption events can be a catalyst for positive change for neighborhoods, such as economic renewal and beautification, and can help shift expectations about and patterns of travel behavior. Disrupting the accessibility of car parking, for example, could be a means to reduce the incentive to drive and to encourage greater use of sustainable mobility alternatives.

Considerations

Transport projects by virtue of their physical structures and long life spans can have long-lasting impacts for a neighborhood. A community's ability to recover from neighborhood disruption can vary. Resilience of neighborhoods to adapt to disruptive change is subject to various factors, such as socioeconomic disadvantage; community cohesion; degradation of environmental assets such as clean air, green space, and ambient noise, as well as economic indicators including property prices, housing affordability, and employment opportunities.

Defining the affected community is important to managing public expectations about the scope of assessments. The neighborhood or community can mean different things to different people. From a pragmatic planning perspective, definitions of a neighborhood are often simplified to mean the people, residents, and businesses within a spatial area, such as a suburb or street.

In contrast, an individual's perspective of a neighborhood is defined by social connections, meaningfulness, and identity, but these are never static. Neighborhoods evolve and neighborhood connections are subject to change in importance. People living outside a spatial neighborhood might have a less intense level of connectivity but could, nevertheless, consider themselves as still having a stake in the neighborhood. Balancing the conflicting perspectives of a neighborhood adds an additional level of complexity for transport planners. Excluding a legitimate section of the neighborhood

from the assessment of impacts is undesirable, but assuming impacts on all neighborhood individuals are equal can distort assessments.

Perceptions of what is an acceptable level of disruption from transport projects vary within the community. At the citywide level, the community might endorse in principle the need to build or enhance transport infrastructure to satisfy the need for fast and efficient connectivity across the city. However, at the microlevel of the neighborhood, the endorsement for such projects varies by the relative exposure to disruption and benefits.

The neighborhoods most affected by disruption are not always the same as the neighborhoods most likely to benefit from the transport infrastructure. For example, transport projects that are designed to increase the speed at which people can travel through the network, such as highways or high-speed transit, could, by design, have limited points of access along the route.

Changes in accessibility are an issue for neighborhood businesses. Accessibility to parking, especially free and plentiful parking, provides businesses with an inherent and comparative locational advantage in attracting customers and remaining competitive. From a business perspective, any reduction in the availability of parking represents a disruption to the norms of doing business. Transport interventions that, therefore, remove parking, even if the objective is to increase sustainable transport options such as transit and cycling, are commonly viewed as threats to business survival.

Businesses will experience economic hardship if they do not adapt easily or in a timely manner to attract customers who are less dependent on car parking. The stresses experienced by the local business community have flow-on impacts to the local neighborhood. If the businesses cannot adapt, the neighborhood business cluster is vulnerable to economic decline, which could ultimately translate to a reduction of local employment and shopping choices. The absence of a thriving local business community providing access to goods (such as fresh and affordable food options), services, and employment is a contributing factor in the relationship between social disadvantage, transport disadvantage, and social exclusion. Assessments of neighborhood disruption, therefore, should also take into account the resilience of the local business community to adapt.

Strategies

Recovery from the disruptive effects of transport projects could be subject to new travel behavior norms being established. In the case of transport projects and interventions designed to increase sustainable mobility options, it could take time for the public to accept and use their new options. For businesses, learning new skills and strategies to adapt to the new environment, so that they can capture value from new mobility options, is important.

Temporary disruptions may be more acceptable than long-term ones to the community, but even the best-planned projects can experience delays. Project delays can test the community's patience and capacity to cope. If the disruptive effects on the neighborhood are long lasting, the community's adaptive capacity needs to be sustained. Taking early action to help businesses adapt to the disruptive effects of transport projects and interventions can help prevent a cycle of decline. Using the disruption events as an opportunity to regenerate and invest in the attractiveness of the business strips and retail precincts, for example, can help generate interest and economic uplift.

Considering neighborhood disruption in the appraisal stage can help identify the context-specific issues that could reduce neighborhood resilience to adapt and benefit from the new transport infrastructure. Sharing information with the community about the opportunities and challenges, and keeping them updated, can help prepare the community for disruption and, where appropriate, alleviate their concerns.

The categorization of neighborhood disruption impacts is not standardized. Reviews of indicators for assessing transport impacts highlight that the overlap between social, environmental, and economic issues at the neighborhood level result in differentiation by context. Neighborhood disruption impacts can be captured under issues of social equity, environmental intrusion effects such as noise and visual impact, interference effects such as barriers to community right-of-way, or economic opportunities.

Economic, social, and environmental impact statements prepared for decision makers can be a useful tool for communicating the merits and trade-offs of a transport project. However, care needs to be taken in using them to communicate about neighborhood disruption. The scale and

scope of issues and measures can be different. For example, macro-level assessments of economic benefits from a transport project, such as travel-time savings, do not easily translate to the micro-level concerns of neighborhood businesses and residents. Likewise, the estimated distribution of benefits ultimately relates to the completion of the project, so they do not reflect the losses experienced by residents or businesses forced to relocate ahead of the project or hardship endured during the construction period. Jurisdictional requirements for impact statements also might vary, but best-practice guides for assessing the localized effects of transport projects can be helpful.

Increasing the sustainability of the transport network is a necessarily disruptive process, because new travel habits need to be formed and inadequate transport links need to be addressed. The willingness of the community to accept the trade-offs will be determined by the value it places on the benefits. Using disruptive events as an opportunity to help the neighborhood adjust might not eradicate the neighborhood disruption, but might help mitigate the longevity and severity of impacts on the area.

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See Also: Construction Management; Construction Management, Public Relations and; Environmental Impacts; Parking Lots; Transit Planning, International.

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Neighborhood Electric Vehicles

Neighborhood electric vehicles (NEVs) are a U.S. regulatory classification of battery-powered electric vehicles that are limited to driving on roads with speed limits of 45 miles per hour (mph) or lower. Many states restrict NEVs even further, usually to roads with a speed limit of 35 mph or lower.

The name refers to the idea of the NEV as a vehicle that can be “driven around the neighborhood,” because, apart from the lack of access to high-speed highways, the battery life will generally not sustain lengthy trips. Most NEVs are similar to the electric cart, which is the most common example and a familiar one from its use both as a security patrol vehicle (such as in malls, parking lots, and college campuses) and a golf cart.

All NEVs are classed by the U.S. Department of Transportation (DOT) as low-speed vehicles. Four states do not allow NEVs on public streets. In a small number of states, most notably California, NEVs can drive on roads with speed limits greater than 45 mph under certain conditions. Legally, an NEV as sold has a maximum speed of 25 mph. The buyer could modify the NEV to achieve a speed of 35 mph, however. Federal safety requirements mandate that NEVs must be equipped with certain basic safety features, including the modern three-point seatbelt, running lights, headlights, brake lights, reflectors, turn signals, and rearview mirrors. Windshield wipers are not required, nor are windshields, or even doors. Some states have additional safety requirements. New York, for example, requires backup lights, speedometers, odometers, a windshield and windshield wipers, and a window defroster.

The crash protection is minimal enough that NEVs are widely considered unsafe for city driving, though they are rarely banned. Further, some have pointed out that the frame of the vehicle and the use of seatbelts makes the NEV safer than bicycles, and the slow maximum speed makes it safer than a motorcycle.

NEVs recharge by plugging into a standard outlet, usually at the owner’s home (or at the place of business where the NEV is used), though there are a small but growing number of electric charging stations in the country as electric vehicles gain support. NEVs do not produce tailpipe emissions and

are classed as zero-emission vehicles in California, making them eligible for rebates offered by that state as an incentive to its residents.

The United States is the largest market for NEVs, with about 15,000 sold in 2011, and about 100,000 in use. The leading manufacturer is Global Electric Motorcars (GEM), a subsidiary of Polaris Industries, formerly owned by Chrysler. Since its first model in 1998, GEM has sold 46,000 of its NEVs. Like most NEVs, GEMs have a range of 30 miles per charge and use a 72-volt battery system that recharges overnight (or in about six hours). Six models are sold, most of them bought by corporate and government agency customers, including university and medical campuses, sports teams, shuttle services, and planned communities. Three of the GEM models are utility vehicles equipped with a flatbed. The utility vehicles and the GEM e2 are two-passenger vehicles. The remaining models



A Global Electric Motorcar (GEM) in service as a police vehicle in downtown Lisbon, Portugal, in 2009. GEMs, made by Polaris, have a 72-volt battery system that takes six hours to charge, and they are able to travel about 30 miles per charge.

are a four-passenger and six-passenger vehicle. The six-passenger is popular as a shuttle service vehicle.

While commercial and government use is the most common use of NEVs, they also have been an important component of certain planned communities, primarily in Florida and California. These communities are designed for slow traffic and minimal need for the frequent long-distance trips commuters in bedroom communities might face. This is true for Celebration, Florida, for instance, a planned community originally developed by the Walt Disney Company, and The Villages, Florida, a retirement planned community. Both were developed with the intention of residents using NEVs for most of their travel needs around the community, and zoning reflects this intention.

In 2011, the Urban Land Institute awarded a Vision Award to Riverside (California) County's Neighborhood Electric Vehicle Plan, which created NEV routes for the four cities of Corona, Norco, Moreno Valley, and Riverside. The plan allows NEVs to be driven on roads with speed limits of up to 55 mph by creating dedicated routes for them, such that their slow speeds neither impede faster traffic nor create a safety hazard. The Riverside plan is considered a model plan of adapting existing communities to encourage NEV use, with minimal infrastructure expenditures.

Other models of NEVs include the following: Blue Sky Design's three-wheeled BugE, which in most configurations is legally classed as a motorcycle because of its 40 mph top speed; the CT&T cZone, from the South Korean company that is the largest manufacturer of battery electric vehicles in the world; AEVCO's Kurrent, which uses four 12-volt batteries and has a 40-mile range; Canadian Electric Vehicles' Might-E Truck, a street-legal utility NEV with regenerative braking and a hydraulic lift; five models of cars and trucks from Miles Electric Vehicles in Los Angeles, sold mainly to universities, the U.S. Navy, and airports; the MIT CityCar designed by the Massachusetts Institute of Technology's Media Lab; and Oka Auto USA's Oka NEV ZEV.

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See Also: Electric Vehicles; Hybrid Automobiles/ Hybrid Electric Vehicles; Low-Emission Vehicles; Zero-Emissions Vehicles.

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Neotraditional Neighborhoods and Transportation Impacts

Neotraditional neighborhoods are built environments that attempt to apply pedestrian-friendly and multipurpose (for example, employment, residence, and local shopping) neighborhood designs from the pre-automobile era (that is, traditional) to modern, urban, and suburban areas. The ultimate goal is to create what resemble modern urban villages that allow residents to work close to home, partake in local entertainment and shopping, reduce automobile use, and increase walking, while also generating a high level of trust in fellow neighbors and a sense of community.

Neotraditional neighborhoods have increased in number and popularity in recent years. Even though neotraditional neighborhoods have sprouted in Europe and the Southern Hemisphere, these trends have been most pronounced within the United States. Consequently, this entry focuses on the development of this trend in the United States since the 1980s.

Neotraditional neighborhoods have been part of a movement to appropriate "land use" for environmental, health, and community quality-of-life goals. These goals and principles are associated with the movements of "new urbanism" and "smart growth," which are urban development and design strategies geared toward addressing urban sprawl,

suburbanization, greenhouse gas emissions, and other sustainability-related phenomena.

Smart growth and new urbanism strategies contend that the built environment—that is, land use patterns, urban design, and transportation systems—if constructed appropriately, can help protect the environment, curb automobile dependence, and generate sustainable communities, as well as contribute to neighborhood-based development and buffer the effects of urban sprawl on farmland and forest degradation. New urbanists emphasize neighborhood design that is based on traditional urban planning from before the 1950s, hence the term *neotraditional neighborhood*.

A central tenet of new urbanism and neotraditional development is to change travel behavior. A critical aim is to reduce car use and increase transit use and walking.

While results are mixed, research generally affirms the efficacy and effectiveness of neotraditional neighborhoods in fulfilling objectives associated with new urbanism, and, more generally, sustainable development. Studies have consistently shown that the built environment of neotraditional neighborhoods is associated with, and at times directly affects, travel behavior. Even though other factors can explain some of the effect that neotraditional neighborhoods have on their residents—for instance, residents' socioeconomic status or the self-selecting process of individuals choosing to live in neotraditional neighborhoods—the fact remains that the built environment of these neighborhoods can influence transportation. More specifically, residents of neotraditional neighborhoods tend to use cars less, walk more for utilitarian reasons, and use transit more than residents of other types of neighborhoods.

New Urbanism, the Urban Village, and Suburbanization

New urbanism and neotraditional neighborhood principles are embodied by the nonprofit organization called the Congress for the New Urbanism (CNU). As stated on the first page of its 2002 "Charter of New Urbanism," the organization aims to accomplish the following:

[restore] existing urban centers and towns within coherent metropolitan regions, [reconfigure] sprawling suburbs into communities of real neighborhoods and diverse districts,

[conserve] natural environments, and [preserve] our built legacy.

CNU works toward these aims because it views disinvestment in central cities, urban sprawl, racial and economic segregation, environmental deterioration, loss of agricultural land and wildlife, and the lack of attention to cultural heritage as interrelated, community-building challenges.

In essence, New Urbanism proponents advocate a built environment, perhaps nostalgically, that resembles the urban villages of the pre-World War II era. Around the turn of the 20th century, the United States began to urbanize rapidly. This urbanization supported the concentration of economic and social activities within cities' central business districts.

Observing the effects of this urbanization, in the 1930s, Louis Wirth made famous the idea of urbanism, which is understood as a specific way of life that is particular to large, concentrated urban areas. This way of life, according to Wirth, was comprised of new types of social relations, social problems, and less cohesive communities. Even though Wirth's notions became popular, other scholars noted that many urban areas were not characterized by such negative aspects. They observed that within certain urban neighborhoods, residents maintained strong communal ties, interacted on a face-to-face basis, relied on walking and public transportation, and engaged in local shopping and entertainment. In other words, certain neighborhoods tended to resemble "urban villages."

These urban villages, in turn, influenced the perpetuation and preservation of symbolic, historical, and cultural meanings associated with cities and neighborhoods. Therefore, prior to the widespread dispersion of automobiles in the United States, many neighborhoods and cities were built for walking, and streets were designed in a manner that was conducive to social interaction. In addition, local histories and cultures were intertwined with the built environment, and farmland was pervasive and more directly connected to urban centers.

Other processes, particularly urban sprawl, were also beginning to occur prior to World War II, and urban sprawl continues to affect U.S. urban structure today. Because of its frequent use, the term *urban sprawl* can have multiple meanings. For the purpose of this entry, urban sprawl is defined as urban

growth and change characterized by the decentralization and deconcentration of the population and economic activities away from central business districts. In this context, decentralization and deconcentration can also be understood as land urbanization, low-density land use, and suburbanization.

Governmental policies abetted by new transportation and communication technologies contributed to and continue to influence urban sprawl. Most important, the widespread use of automobiles, along with zoning regulations and federal highway construction, influenced urban sprawl. Although many factors feed into urban sprawl, transportation technologies, and specifically, the automobile, are arguably primary catalysts.

As a result of the ubiquity of automobiles in conjunction with other urban development processes, the 1950s marked the greatest period of suburbanization in U.S. history, and by 1990, almost 50 percent of Americans lived in suburbs. This deconcentration, decentralization, suburbanization, low-density land use, and land urbanization remain prominent urban processes, and they have wide-ranging effects. For instance, urban sprawl can affect the environment in multiple and complex ways. Low-density land use has led to the conversion of farmland and forests into built environments, and, as a result, it has exacerbated the extinction and loss of native species, as well as increased greenhouse gas emissions as a result of increased automobile use.

The deconcentration and decentralization of population and economic activity away from central cities has also had a profound effect on the communities and neighborhoods that remain in central cities. Suburban neighborhoods tend to be wealthier and healthier than center-city neighborhoods, and dramatic racial and economic segregation is arguably a prominent side effect.

The urban planning principles associated with neotraditional neighborhoods are a response to these urban dynamics. And, just as transportation influenced sprawl and suburbanization, new urbanists and neotraditional designs aim to alter travel behavior. Put differently, because transportation contributed to urban sprawl and its consequences, neotraditional neighborhoods are designed to impact transportation and make travel behavior more sustainable, thus reducing sprawl and its impact.

Following the logic of “traditional” neighborhoods, new urbanism’s principles pertaining to neighborhood design include the following: neighborhoods and streets should be designed so that citizens interact and are encouraged to contribute to maintenance of the local area; neighborhoods should be dense and mixed use; activities should occur within walking distance, which would increase walking and reduce automobile use; neighborhoods should include housing that facilitates diversity of age, race, and income; and neighborhoods should be oriented around public transit.

Measuring Travel Behavior and the Built Environment

Transportation measures in empirical research on neighborhoods’ influence on travel consist of vehicle miles traveled (VMT), walking behavior, and transit use. Thus, travel behavior consists of at least three modes: auto, transit, and nonmotorized. These three modes are also broken down further by trip length and trip frequency. In addition, there are different forms of travel. For example, there are multiple forms of walking, such as destination walking (that is, travel) as opposed to leisure walking.

Built environment characteristics of neighborhoods that are frequently tested in this line of research can be succinctly summarized by the five “D variables.” These D variables are density, diversity, design, destination accessibility, and distance to transit. The first three—density, diversity, and design—are more frequently studied, but all five are important.

Density is the most frequently studied characteristic, and measures and definitions can be quite different across studies. Measures have included density of population, dwelling units, employment, and building floor area, along with proxies for social and economic characteristics. Diversity commonly refers to the number of different land usages in an area, and high levels of diversity indicate that a neighborhood is a mixed-use environment (that is, employment, entertainment, and housing). Design is understood as street connectivity. Measures can include dense urban grids, sparse suburban streets, and the types and number of intersections. Measures of design tap into the construct of pedestrian-friendly areas versus auto-friendly areas, and so measures have included sidewalk coverage, street trees, and so forth.

Destination accessibility measures the ease of access to trip attractions, such as distance from the central business district. Distance to transit is commonly measured as the average (or some other metric) distance from residential areas or workplaces to the nearest rail station or bus stop in an area.

Transportation Impacts

Do neotraditional developments and their built-environment characteristics influence travel behavior? In general, empirical studies support new urbanism claims. Research for decades has shown that physical, social, and environmental characteristics of neighborhoods influence social lives and behavior, and the impact of neotraditional neighborhoods on transportation is no exception.

Past research demonstrates that residents in neighborhoods with high density, high destination accessibility, mixed land use, and high street connectivity, and that are closer to urban centers, tend to use cars less and walk more compared to residents in suburban neighborhoods characterized by single land use, less accessibility, greater sparseness, less street connectivity, and greater distance from urban centers. However, important differences exist across the different relationships between each specific built-environment characteristic and travel behavior.

As an illustration, while density is the most commonly studied characteristic of neotraditional neighborhoods, its relationship with travel behavior is the most tenuous. In fact, density has the weakest overall relationship with travel behavior compared to all other characteristics. Multiple studies find, for example, that density is associated with the purpose of walking, but not overall walking or physical activity. That is, residents in less dense neighborhoods engage in more leisure walking, while residents in more dense neighborhoods engage in more destination walking (for example, going to the local store).

Of the five major D variables, destination accessibility is most strongly related to travel behavior, including both motorized and nonmotorized travel. In particular, more accessibility is strongly related to fewer vehicle miles traveled. Design measures are also important for travel behavior, but are less important than destination accessibility. Short blocks and more street interconnections can shorten travel distances and increase walking frequency, with intersection density being the most important design measure for walking behavior.

Diversity also plays a role in travel behavior, because creating a good jobs–housing balance and allowing residents to live near where they work induces more frequent walking. Additionally, locating residences near bus stops can lead to more transit use, and nearby transit stops can lead to more frequent walking. Mixed land use can also make it possible for transit users to run errands at transit stops, again reducing automobile use and increasing walking.

It is also important to consider that neotraditional neighborhoods are embedded in a larger urban structure. The regional characteristics of this greater structure have been shown to influence VMT above and beyond the effect of other neighborhood characteristics. In particular, the distance of a neighborhood from the central city is strongly related to VMT. Residents in neighborhoods farther from the center city drive more than their counterparts located closer.

Therefore, factors such as distance from regional shopping centers and central business districts influence automobile use for residents in different types of neighborhoods, regardless of other characteristics of a given neighborhood. Thus, planning strategies that focus on neighborhood development and design need to consider regional characteristics, keeping in mind that regional development is as important for transportation as is local neighborhood design.

Similar to other research on how neighborhoods influence individuals' behavior, self-selection, or the fact that certain individuals choose to live in certain neighborhoods, may explain why the characteristics of neotraditional neighborhoods can impact travel behavior. Research shows that individual characteristics of residents in different neighborhoods influence walking behavior, automobile use, and transit use.

As an illustration, socioeconomic status is associated with travel behavior, because wealthier individuals own more cars and have more choices in terms of travel modes. The number of trips taken and transportation mode choices are influenced by individual-level characteristics, such as socioeconomic status, regardless of the built environment of neotraditional neighborhoods. However, sophisticated statistical analyses have allowed researchers to decipher the difference between neighborhood design effects and the effects of individual-level

characteristics. This allows researchers to examine how neotraditional neighborhoods influence travel behavior while accounting for the fact that certain individuals choose to live in certain neighborhoods. Taken together, this gives a clearer picture of built-environment effects.

Research shows that neighborhood characteristics can influence travel behavior even after accounting for individual differences. In fact, some research has even shown that the effects of the built environment are stronger after accounting for individual-level characteristics, making it clear that individual characteristics are also important to consider. In sum, neotraditional neighborhoods, based on pedestrian-friendly and new urbanism principles, are designed to generate sustainable communities, and they contribute to this end by influencing travel behavior.

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See Also: Health Issues; Mode Share/Mode Choice; Pedestrian-Friendly Design; Smart Growth; Urban Sprawl Versus Compact Development.

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Network Modeling

Networks are objects comprised of nodes (also referred to as edges) that are connected by links (also referred to as arcs). This definition is very flexible and can tackle many forms of relationships or connections that define the links. Through this flexibility, it is easy to find networks in many domains.

Historical Background

Network theory is an area of applied mathematics that represents a domain of graph theory. A network model implies an abstraction of reality that helps simplify a problem. Applied mathematics, computer science, engineering, management, and operational research are scientific domains that use network theory.

The beginning of network theory can be traced back to the well-known problem of the seven bridges of Königsberg in Germany. The stated problem was to find a walk through the city that crosses each bridge once and only once. In 1735, Leonhard Euler proved that this was not possible. He reformulated the problem and constructed a network by replacing each landmass with a node and each bridge with an arc. The study of the network led to the identification of valuable properties of the problem and then to its solution, presenting the first steps of network theory.

Because "network modeling" is a general term, developed in many scientific domains, the focus is to analyze the most significant network modeling methods with applications in transportation. In transportation networks, the main objective is to model the objects' movement through the networks. Thus, the most significant work refers to network flow modeling.

This field traces its roots back to 1845, to the work of Gustav Kirchhoff and scientists who first systematically analyzed electrical circuits. However, research on transportation network flow modeling is much more recent. It can be traced to the late 1940s, when the research and practitioner communities simultaneously developed optimization as an independent field of research. Several important network optimization problems related to transportation include the "shortest path" problem, the "traveling salesman" problem, the "vehicle routing" problem, the "multi-commodity flow" problem, the "network design" problem, the "assignment"

problem, the “transportation” problem, and the “minimum spanning tree” problem.

Transportation Flow Modeling Problems

In 1939, Leonid Kantorovich introduced the idea of linear programming. Some years later, in 1951, George Dantzig reinvented and further developed this field. Both researchers’ motivation came from fundamental transportation problems.

The minimum cost flow model is the most general network modeling problem. The problem aims to determine the least costly shipment of goods, in order to satisfy demand at central nodes from available suppliers from other central nodes. The most significant special cases of minimum cost flow problems are the shortest path, the transportation, the transshipment, the assignment, and the maximum flow.

Minimum Cost Flow Problem

First, assume that the problem can be presented by a directed graph $G(N,A)$ where N is the set of n nodes and A is the set of m -directed arcs. Each arc $(i,j) \in A$ has an associated cost $c_{i,j}$, the cost per unit flow on that arc. It is also assumed that the cost varies linearly with the amount of flow. Associating each arc $i,j \in A$ with its upper and lower bounds denotes capacity and minimum amount of flow on the arc.

Each node $i \in N$ is associated with an integer number $b(i)$ representing its supply/demand. If $b_i > 0$, node i is a supply node; if $b_i < 0$, node i is a demand node, and if $b_i = 0$, the node is a transshipment node. The decision variable $x_{i,j}$ represents the arc flows on $i,j \in A$.

The formulation of the linear programming problem can be stated as follows:

$$\begin{aligned} & \min_{(i,j) \in A} c_{i,j} x_{i,j} \\ & \text{Subject to} \\ & \{j:(i,j) \in A\} x_{i,j} - j:j,i \in A x_{j,i} = b_i \text{ for all } i \in N \\ & l_{i,j} \leq x_{i,j} \leq u_{i,j} \text{ for all } (i,j) \in A \\ & \text{Where} \\ & \sum_i b_i = 0 \end{aligned}$$

The first set of constraints guarantees that the total outflows of a node minus the total inflows of a node is equal to its supply/demand. The second set of constraints includes the flow bound of each arc. In order to have a balanced problem, the last

equation, which states that total demand is equal to total supply, needs to be satisfied.

Shortest Path Problem

The shortest path (SP) problem is considered one of the simplest network problems. For this problem, the aim is to find the minimum cost or length from an origin node o to a destination node d , assuming that each arc (i,j) has an associated cost $c_{i,j}$. This basic model has applications in project scheduling, cash flow management, message routing in communication systems, and traffic flow.

The problem can be defined in directed, undirected, or mixed graphs. The problem can also be distinguished from the overall aim if the objective is to find a single pair, single source, or single destination, or even all pairs SP. The literature typically classifies algorithmic approaches for solving SP in two groups: label setting and label correcting. Both approaches are iterative. They assign distance labels to nodes at each step. The two approaches vary in the way they update the distance labels from step to step and in how they converge.

The most significant and well-known SP algorithms are Dijkstra, which solves the single sources versions of the problem; Bellman-Ford, which solves single sources versions even with negative-edge weights; and Floyd-Warshall, which solves all pairs’ SPs. Lately, several heuristics have been developed, aiming to speed up the search by preprocessing techniques. Such algorithms are A^* or ALT algorithm. The linear programming formulation that applies to the shortest path problem can be expressed as follows:

Assuming that $G(V,E)$ is a directed nonnegative graph, and the aim is to find the shortest path from origin node o to destination node d . V is the set of nodes and E is the set of arcs, and $c_{i,j}$ is the cost traveling for each arc $(i,j) \in E$.

The objective function aims to find the path with the minimum cost and, therefore, can be stated as

$$\begin{aligned} & \min_{i,j \in V} c_{i,j} x_{i,j} \\ & \text{Subject to} \\ & j \in V x_{i,j} - j \in V x_{j,i} = 1 \\ & \text{if } i = o - 1 \\ & \text{if } i = d 0 \text{ for all } i \in V \\ & x_{i,j} = 0 \text{ or } 1 \end{aligned}$$

The constraints secure the following three cases:

1. From an origin node, only one node is selected to be visited;
2. only one node is selected to reach the destination node;
3. for all other nodes in the path, there is only one arc that is entering the node and only one arc that is exiting it.

In special cases where the objective is to determine the shortest path from an origin node to all other nodes, then the right part of the inequality is $n - 1$ for $i = d$ and minus 1 for all other nodes.

Transportation Problem

The transportation problem is a special case of the minimum cost flow problem, which is one of the most fundamental of all network flow problems. The aim is to determine a least cost shipment of goods from a set of nodes that represent warehouses to a set of nodes that represent customers, using all alternative distribution channels. The problem is constrained by the restrictions of production of each warehouse and the demand of each customer, as well. Frank Lauren Hitchcock formulated the transportation problem in 1941. At the same time, Tjalling Charles Koopmans also researched the problem, developing the idea of point potentials and an optimality criterion. Because of the initial work of both researchers, the problem is also referred as Hitchcock-Koopmans transportation problem.

However, in 1951, George Dantzig formulated and solved the problem by using the framework of linear programming.

The linear formulation of the transportation problem can be expressed as follows:

Assuming that m warehouses $S_1, S_2, \dots, S_m$ can supply $s_1, s_2, \dots, s_m$ quantities of a product, and that the product has to be transported to n customers $D_1, D_2, \dots, D_n$ that require the following $d_1, d_2, \dots, d_n$ quantity, then the cost for transportation from $S_i \rightarrow D_j$ is expressed by $c_{i,j}$

$$\min z = \sum_{i,j} c_{i,j} x_{i,j}$$

Subject to

$$\sum_j x_{i,j} = s_i \quad \forall i = 1, 2, \dots, m$$

$$\sum_i x_{i,j} = d_j \quad \forall j = 1, 2, \dots, n$$

$$x_{i,j} \geq 0 \quad \forall i, j$$

The first group of constraints guarantees that each warehouse's total outgoing shipment cannot exceed its ability to supply. The second group of constraints states that the incoming shipment of each customer cannot exceed its demand for the product.

In order to have a feasible solution to the problem, it is necessary to make sure total supply is not less than total demand. However, when the total supply is less than total demand, it is still possible to create a balanced transportation problem. This can be established by creating a dummy source and assigning to it a supply equal to the difference between total demand and supply.

Assignment Problem

The assignment problem is a special case of the transportation problem, aiming to identify a perfect match of minimum weight between two equivalent subsets. It was investigated first in 1784 by Gaspard Monge, whose motivation came from the problem of transporting molecules.

In 1912, Jenö (Eugene) Egerváry and Denes König examined it in the framework of matching theory and bipartite graphs. Assuming that $G = (N_1 \cup N_2, A)$ is a weighted bipartite network with $|N_1| = |N_2|$ and $c_{i,j}$ is the arc weight that represents a cost, then the general assignment problem can be stated as the following linear program:

$$\min z = \sum_{i,j \in A} c_{i,j} x_{i,j}$$

Subject to

$$\sum_j x_{i,j} = 1 \quad \text{for all } i \in N_1$$

$$\sum_i x_{i,j} = 1 \quad \text{for all } j \in N_2$$

$$x_{i,j} \geq 0 \quad \text{for all } i, j \in A$$

The assignment problem is also known as the bipartite weighted matching problem. The best-known algorithms that are used to solve the problem are the network simplex algorithm and the Hungarian algorithm. Harold William Kuhn in 1955 explained how the works (from 1931) of two Hungarian mathematicians, Denes König and Jenö (Eugene) Egerváry, had contributed to the invention of his algorithm, named the Hungarian method.

Maximum Flow Problem

The maximum flow problem through a network was initially stated in a report in 1954 by L. R. Ford and D. R. Fulkerson. The problem is stated to be the complementary problem of shortest path. Both

problems seem similar because they both arise as subproblems of the minimum cost flow problem. However, they differ because they capture different aspects of the problem.

In general, the maximum flow problem's aim is to find the path between two nodes in a way to accommodate as much flow as possible, without exceeding the capacity of any arc and mass balance constraints at nodes. In order to formulate the problem, it is necessary to consider a directed capacitated network $G(N,A)$. Each arc is associated with a capacity $u_{i,j}$. To define the maximum flow problem, two special nodes, namely source node s and sink node t , are defined. The problem can then be formulated as follows:

$$\begin{aligned} &\text{max} \quad x \\ &\text{Subject to} \\ &j: i, j \in A, x_{i,j} - j: j, i \in A, x_{j,i} = u \text{ for } i = s, 0 \text{ for all } i \in A - \{s, t\} - u \text{ for } i = t \\ &0 \leq x_{i,j} \leq u_{i,j} \text{ for each } (i,j) \in A \end{aligned}$$

It is noteworthy to state that following the strong duality theorem of linear programming, the "max flow min cut" theorem was derived. The theorem expresses that the maximum value of s - t flow is equal to the minimum capacity over all s - t cuts.

Therefore, the "min cut dual" problem can be formulated as follows:

$$\begin{aligned} &\text{min} \quad \sum_{i,j \in A} c_{i,j} d_{i,j} \\ &\text{Subject to} \\ &d_{i,j} - p_i + p_j \geq 0 \text{ for all } (i,j) \in A \\ &p_s - p_t \geq 1 \\ &p_i \geq 0 \text{ for } i \in A - s \text{ and } t \\ &d_{i,j} \geq 0 \text{ for all } (i,j) \in A \end{aligned}$$

The best-known algorithm for solving the max flow min cut problem is the Ford-Fulkerson algorithm. From the initial directed graph, the residual graph is derived and that the procedure starts with an empty flow. An initial s - t path has to be calculated, and then the flow is updated along the path and the residual graphs until there is no s - t path in the residual graph. The method is based on the augmenting path.

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See Also: Activity-Based Models; Destination Choice Models; Full-Feedback Modeling; Mode Choice Models; Transportation Modeling and Planning Software; Travel Modeling.

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Next Generation Airports, Federal

In engineering and the hard sciences, "next generation" refers to a current or in-development technology that significantly advances a particular application. The process of transitioning federal airports to a group of next generation technologies is sometimes abbreviated as "NextGen." NextGen describes the process of moving to a satellite-based system of air traffic management from a ground-based one. In the context of increasingly scarce resources, intensifying global climate change, and possible terrorist attacks, the Federal Aviation Administration (FAA) has been part of the attempt to delineate the contours of the next generation of airports and of air travel more generally.

The key concept is one of integration of efforts, with a gate-to-gate approach designed to minimize the energy expended by passengers or, from another perspective, to minimize the ability of the paying public to interfere with the smooth running of the operation of air flights. The FAA claims that with careful organization of the different

components of a flight between taxiing to and from the gates, it will be possible to shave seconds or minutes from each individual stage and this, as a whole, will lead to substantial savings in terms of time and efficiency.

The Next Generation Air Transportation System (NGATS) is the new National Airspace System (NAS), implementation of which began in 2012 and is scheduled to continue in stages through 2025. The NAS is the managed aviation system of the United States and the flights and facilities involved. The key aspect of NGATS is transitioning the NAS's air traffic control system from a ground-based system to a satellite-based system, using GPS to allow flights to follow more direct routes and fly closer together. NGATS is designed primarily to decrease air transportation congestion and to save billions of dollars in so doing. The automatic dependent surveillance-broadcast (ADS-B) system that is the cornerstone of NGATS uses GPS transponders to track aircraft positions and broadcast real-time air traffic information to pilots and air traffic controllers. The Next Generation Network-Enabled Weather (NNEW) system reduces weather delays by similarly providing a more complete picture of the weather by gathering real-time information from tens of thousands of sources. Communications are improved through a unified NAS voice switch program, replacing the 17 different voice switching programs previously in use, and the Next Generation Data Communications system that augments voice communication through electronic data communication, reducing air traffic controller workload and reducing distractions while improving information access.

The Joint Planning and Development Office was tasked with overseeing the development of NGATS in 2003, and identified an "agile" air traffic system as one of the key areas in which research and development were needed. Research facilities like the National Aeronautics and Space Administration (NASA) Ames Research Center have worked to meet this need, such as through the development of Cooperative Air Traffic Management (CO-ATM), which improves efficiency and capacity by changing the way tasks are distributed among air traffic controllers on the ground and flight crews in the air. While sector controllers control aircraft on their flight paths, for instance, and area controllers control trajectory changes, controllers

delegate certain tasks to flight crews, like spacing between aircraft. CO-ATM is envisioned as a way to transition from the current system of air traffic management to one in which computer systems handle most air traffic systems while controllers act as supervisors.

The most recent implementation of NGATS is the adoption in August 2013 of the Time-Based Flow Management (TBFM) system in air traffic control centers. TBFM replaced the Traffic Management Advisor system and was developed by Lockheed Martin as part of a 10-year contract awarded in 2010. The new system is expected to reduce delays in airports at greater than 70 percent capacity, and improves trajectory predictions.

It is anticipated that a satellite-based system and enhanced technology will enable the handling of more airplanes than at present, thereby decreasing time spent waiting for takeoff and landing permissions. Because this is a federal-level program, it requires individual airports and their managers to buy into the concept and then to incorporate it in their own facilities. For this to occur, it should be apparent to those airports that the benefits to be obtained outweigh any costs involved.

The FAA's principal approach is to emphasize improvements in efficiency and, hence, cost savings. Better application of science means, for example, that aircraft can be handled in low-visibility conditions through a combination of the Wide Area Augmentation System (WAAS) and the Localizer Performance with Vertical Guidance (LPV), resulting in pilots being able to land their craft with greater efficiency.

The purpose of NextGen as a strategy—which is echoed by comparable efforts in other parts of the developed world—is not change for its own sake but the need to accommodate significant changes in the nature of air transportation in the foreseeable future, as well as to address known problems of efficiency and to modernize systems. Some of these shifts include the enormous increase in budget air travel, the expansion of the flying population with people around the globe who had not previously traveled by air, and the need for greater efficiency in the use of fuel in a world in which the amount of hydrocarbon fuels is rapidly declining and the price of remaining supplies is inexorably rising.

Two other factors have important implications for the efficient management of air space global

climate change and the threat of terrorism. Climate change is becoming increasingly evident in a profusion of extraordinary weather events, which have a major impact on transportation of all sorts. Terrorism has become particularly critical ever since the attacks of September 11, 2001, which featured aircraft as horrifying weapons.

Governments around the world have seized onto the risk of terrorism as a reason for intensifying scrutiny of people within their jurisdictions. Controlling air transportation provides an unusually close interaction between governments' desire for greater control of people's activities and the willingness of the private sector to comply with these requests. There is little doubt that traveling by air these days, particularly in the United States, is significantly less comfortable and enjoyable than it was before September 2001, even though the gains in terms of safety and security are difficult to identify independently. Under these conditions, therefore, there is a need for a new paradigm of customer management in the air transportation industry that is based on security, safety, efficiency, and at least an approach toward sustainability.

Technology and Labor

When new technological applications are introduced into an industry, people working in that industry tend to show some resentment and resistance, resulting from the long history of job losses that has traditionally followed such changes. In the case of skilled or professional labor, such as pilots, there is the additional concern that technology will remove or reduce the intellectual or skilled component of the work, thereby reducing the status of the job and the satisfaction that can be drawn from it. Improving safety standards have already reduced the role of the pilot through the increased use of autopilots, on the basis that controlled flight into terrain—a crash caused by pilot error—is an all-too-common form of air accident. Therefore, discussions on the introduction of changes to be brought about by NextGen will concern the distribution of power between pilots and air traffic controllers, as well as the issue of cost.

In the United States, there are a number of small, independent contractors offering passenger and cargo services. If the FAA is hoping to persuade airport managers to incorporate NextGen technologies across the board, which would be important for

economies of scope and scale to become effective, the agency will need to persuade small operators, too, to compromise their independence of operation and modify their approach. This is not impossible, of course, because people in air transportation are regularly required to cope with significant technological changes.

Consistency Across Borders

Not only is it necessary to ensure consistency of air travel operations across North America, it is also important to have consistency of operations with other countries. Although Europe is an important destination and source of travelers for the United States, preliminary attempts to create interoperability between NextGen and the Single European Sky (SES) program have been shadowed by strikes by French air traffic controllers. The strikers maintain that the attempt to consolidate national-level control schemes into nine international sectors (called functional airspace blocks) is, in reality, an attempt to privatize the service.

The European Commission argues that inefficiencies in the current system add an average of 26 miles (42 kilometers) to each flight. The importance of international norms for safety and procedure was underlined in 2010, when volcanic eruptions in Iceland spewed volcanic ash into the atmosphere, leading to shutdowns of airports all over Europe and stranding millions of passengers. Disputes broke out among airports that disagreed over the need to ground flights. Global climate change incidents that affect weather patterns are also reinforcing the understanding that air travel, like many long-distance activities, requires a transnational approach to problem resolution.

Additional Problems

As a public-sector-led development, NextGen is also bedeviled by the political ideology in the country that argues for the primacy of private-sector operations over public-sector ones, which are characterized as "big government." In spite of such objections, no private-sector organization or consortium has come forward to make the massive investment in research and infrastructure development that the government is making in this context. However, ongoing budget battles make the ongoing support of NextGen, like numerous other government initiatives, somewhat uncertain.

Even if well funded, projects of this scale tend to experience budget growth beyond what is initially anticipated, and so perseverance over the medium- to long term will be important in the context of possible changes of policy under future presidents and Congresses. Already, the program's completion date has been pushed back from 2014 to 2016 and the cost overrun estimates are starting to reach \$500 million.

Problems also have been identified in technology, particularly with the software program at the heart of computerization of the system—En Route Automation Modernization (ERAM)—which exhibited bugs when first put into use. With political discourse about NextGen generally divided along predictable party lines, it remains to be seen whether the program will be implemented as a whole in the format initially envisaged or if reductions will be made. If the project is scaled back, new questions will arise about how the finished model will perform and whether it will ever fulfill its promise.

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See Also: Air Traffic Control; Federal Aviation Administration; National Airspace System.

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Nitrogen Oxides

The group of chemicals known as nitrogen oxides (NO_x) are constructed on the molecular level of different numbers of nitrogen and oxygen atoms. The two most common members of this chemical group are nitrogen dioxide (NO_2) and nitric oxide (NO). The nitrogen oxide chemical group is not to be confused with nitrous oxide (N_2O); while nitrous oxide is also a greenhouse gas, it is of a different chemical classification and possesses different chemical properties than nitrogen oxides.

Nitrogen oxides are created by both natural and artificial means. However, although some nitrogen oxides are created naturally, those natural sources are dwarfed by those of artificially created nitrogen oxides. These gases are created naturally by thunderstorms, and created artificially by high-temperature combustion, such as that found in coal-burning engines, petroleum-burning motor vehicles, industrial boilers, and other uses of fossil fuels.

The environmental impacts of these pollutants are significant; they contribute to acid rain, global warming, and other equally serious hazards. The personal health impacts attributed to nitrogen oxides typically manifest in the form of, but are not limited to, ailments of the lungs and respiratory system. Luckily, while the negative implications of this type of pollution are daunting and ever present, there are measures that can be taken on the societal level, the local level, and the personal level to mitigate these effects.

Environmental and Health Impacts

Emissions of nitrogen oxides go nearly hand in hand with the use of fossil fuels as an energy source. These emissions also provide one of the best reasons to curb or eliminate the use of these fuels. The chemical composition of nitrogen oxides allows

them to be easily combined with other pollutants; this can then cause the formation of separate toxic substances. For example, nitrogen oxides could combine with sulfur dioxide to create acid rain, acid fog, acid snow, or harmful dry particulates. Once created, these substances, which are made up of nitrogen oxides and sulfur dioxide, are capable of harming cars, new and historic buildings, bodies of water, and water-dependent ecosystems.

In addition to creating acid rain and similar substances, nitrogen oxides also damage bodies of water via eutrophication, a process that occurs when the atmosphere of a given region possesses an excess of nitrogen oxides. In this situation, the ecosystem attempts to balance the excess nitrogen oxides by absorbing them into available bodies of water. If severe enough, this process may impact the ecosystems contained in those water bodies by changing the chemistry of the water and, in turn, inhibiting the absorption of oxygen into that water. Finally, when water is depleted of oxygen, animal life is unable to flourish, or even survive. This problem has been particularly damaging in the Chesapeake Bay, where the absorption of nitrogen oxides created massive dead zones in the 1970s and 1980s; the bay is still suffering the ill effects of this problem to this day.

Additional harmful effects of nitrogen oxides include global warming and the stunting of plant growth. Nitrogen oxide has been shown to be a greenhouse gas. As such, the introduction of massive quantities of these chemicals into the atmosphere is causing worldwide temperatures to rise. The corresponding increases in temperatures have been proven to be causing glaciers to melt on an unprecedented scale. This melt, in turn, has caused sea levels to rise. While glaciers are not yet completely melted, rising sea levels have already caused the destruction of human settlements and numerous ecosystems. This destruction will only continue unless radical changes are made to the way human society produces energy. The leading cause of nitrogen oxide introduction into the atmosphere is automobile emissions, followed by electrical power plants.

Nitrogen oxides could also cause food shortages in the near future. These substances have been shown to hamper plant growth by inhibiting the plants' metabolic processes. If the plants in question happen to be those that humans grow for food,



A researcher at the U.S. Department of Energy's National Transportation Research Center performs tests on a Mercedes A170 diesel engine, using experimental equipment created to study nitrogen oxide-trapping devices to reduce emissions.

this process then will harm crop yields and diminish food supplies. Furthermore, excess levels of nitrogen oxides in the atmosphere can dim the level of sunlight, which may cause a variety of negative impacts on plant and animal life, including additional reduction in crop yields.

Excessive levels of nitrogen oxides are particularly harmful to susceptible populations, including children, people with lung diseases, and those who work or exercise for prolonged periods. People who are regularly exposed to nitrogen oxides can develop acute respiratory illnesses, such as asthma. Even slightly elevated levels of nitrogen oxides can irritate the lungs of members of these groups or make them more susceptible to infections such as influenza. Higher levels of nitrogen oxides can even harm healthy individuals by causing shortness of breath, collection of fluid in the lungs, burning

spasms, throat swelling, reduced oxygen intake, fluid in the lungs, and even death.

What Is to Be Done?

Despite the grave dangers posed by excess levels of nitrogen oxides, measures can be taken on the large-scale and local levels to curb those dangers. On the national scale, the Environmental Protection Agency (EPA) does regulate nitrogen oxide emissions from power plants and motor vehicles, and limits emissions to those below a level of 0.053 parts per million in the surrounding atmosphere. In addition, because wind patterns can spread air pollutants over vast areas, the EPA has also instituted special regulations for upwind areas so that they do not unduly impact other areas.

There are also a number of measures that individuals can take to reduce nitrogen oxide emissions. Possibly of greatest impact, individuals or families can reduce the amount they drive. Other meaningful measures to reduce nitrogen oxide include the replacement of older, gas-powered appliances with electric ones (preferably fueled by non-carbon-based energy sources) and the cessation of cigarette smoking, which also emits nitrogen oxides.

From a political standpoint, individuals or organizations can support efforts for the development and implementation of renewable power sources, either through activism or electoral methods. Individuals also may take their health into their own hands by limiting their personal exposure to nitrogen oxide; the best way to do this is to avoid living in cities or near highly industrialized areas.

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See Also: Air Pollution, Automobiles; Air Pollution/Air Quality; Mobile Emissions; National Ambient Air Quality Standards.

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Noise Pollution and Airplanes

Noise pollution is the most frequent source of conflict between an airport and its neighbors. Airport noise is measured and mapped via noise contours and modeled based on runway dimensions and aircraft operations, with extra weight given to nighttime operations. Within the United States, in determining where noise is greatest, the Federal Aviation Administration (FAA) averages aircraft noise over a 24-hour period. This results in a day-night level (DNL) of noise recorded as, for example, 65 DNL. At this level, the average noise is 65 decibels (dB), about the equivalent of a blender or a garbage disposal. Individual events (that is, planes passing overhead) can be over 90 dB, about the level of a rock concert, but when averaged with periods of silence, they result in a more moderate DNL value.

DNL levels are constructed via computer modeling, including data on the mix of aircraft at a particular airport, how noisy those aircraft are, how many operations there are per day, varying climatic conditions, and the altitude of the flight paths. A similar methodology is used in other countries, although the name might be different. In the 1990s, approximately 5 million people across the United States lived inside the 65 DNL. After international restrictions on aircraft noise went into effect in



A noise meter displays a reading of over 86 decibels as an airplane passes over Neptune Road in Boston, Massachusetts, near Logan Airport, in 1973. In the 1960s, local communities began to advocate for noise reduction and noise standards to benefit those living near airports.

1999, that number dropped to 323,000 people, although this does not mean that quality of life or property values rebounded in value. At the same time, the noise level may be offset for some residents by increased accessibility to jobs. The consistency of the effects of airport noise on property values over three decades of study, even as jet aircraft have gotten quieter, is noteworthy.

There are two main sources of noise from an aircraft: drag or resistance around the various parts of a plane, and the engine. First, the airframe itself introduces a certain amount of noise, particularly as flaps, slats, and wheels are deployed for landing to increase the surface area exposed to the air. Studies have found that once the landing gear has been deployed, the noise experienced on the ground can increase by up to 10 decibels (dB). Because of the logarithmic scale of decibels, this is equivalent to a doubling of noise.

Generally speaking, any improvements to the airframe that reduce noise do so by enhancing the

aerodynamics of the plane. Such improvements are therefore attractive to airlines seeking to reduce fuel costs and are not likely to be controversial.

The greatest contributor to aircraft noise, however, is the engine. Simply put, a jet engine works by pulling in air through a fan and then compressing that air through a series of smaller-bladed fans until it is dense and highly flammable. When jet fuel is introduced into the compressed air and burned, the rapidly expanding air is forced out the back of the engine (and turning turbines that make the fans rotate), propelling the engine and, thus, the aircraft forward. The fans generate considerable amounts of noise, as does the exhaust coming out of the engine.

Engine noise dominates on takeoff and while cruising, whereas noise from the airframe may actually be most noticeable upon landing. Many measures to reduce noise can enhance engine efficiency. For example, one of the major jet engine improvements of the 1970s, the high-bypass turbofan engine, lets most of the air that it pulls in flow around the compression and combustion areas rather than through them, providing some insulation from the noise being generated within. However, some noise improvements can actually increase drag and slow the plane down, making them less likely to be adopted by aircraft manufacturers.

While propeller-driven engines are not entirely quiet, there was a significant jump in noise when propeller planes started to be replaced with the first jets in the 1960s. Pressure from local communities and governments led to the introduction of noise certification in the United States in 1968 through the Aircraft Noise Abatement Act. This meant that aircraft manufacturers had to meet noise standards before their planes could be allowed into service, the same way they already had to meet safety standards.

International multilateral agreements resulted in significant noise reductions in 1988 and again in 1999. In contrast to the noise measurement of the DNL, which is averaged over a period of time, these standards were based on one-time measurements of noise as experienced upon takeoff and landing as an aircraft flew overhead, as well as a measurement to the side of the plane on takeoff. Aircraft that did not meet the noise restrictions had to be completely replaced (obviously, an expensive proposition); have their engines replaced; or have

a “hush-kit,” similar to a muffler, fitted over their engines in order to meet the new noise limits. Different airlines chose different solutions, resulting in significant variation in noise levels from airline to airline and even airplane to airplane.

Beyond changes to the aircraft, airports have introduced a number of techniques to reduce the noise experienced by those on the ground. Early restrictions included upper limits on the weight of aircraft, which increased the rate at which planes could climb but reduced airline revenue in the process.

One of the most common techniques used by airports today is preferential runway usage. When wind conditions permit, runways that point over more densely populated areas are avoided by air traffic control in favor of those aimed at open space or industrial areas. Similarly, flight tracks for arrival or departure may be modified to either concentrate noise over compatible uses or spread it out over incompatible areas. This can be seen at Minneapolis–St. Paul International Airport, where aircraft taking off to the southwest are directed to maintain a constant heading that keeps them over industrial land, while aircraft taking off in the reverse direction are given slightly different headings from one another to distribute the noise more broadly over a heavily residential area.

Beyond the route an aircraft takes, pilots may also be directed to reduce the initial thrust of their aircraft until they have reached a suitable altitude. At some airports, such as O'Hare International in Chicago, community organizations have met directly with air traffic control staff and pilots to persuade them to use preferential runways and/or flight tracks.

Aircraft also generate noise on the ground, whether on the runways and taxiways or elsewhere. This noise can be abated in three main ways: relying more on braking and less on reverse-thrust engines to slow the aircraft once it has touched down; doing maintenance tests of engines only during regular airport operating hours, rather than in the late night or early morning; and using ground vehicles to push back from gates and taxi the plane, rather than relying on aircraft engines.

Low-frequency noise can also be an issue in locations parallel to the runway. This noise is more like a vibration than an audible sound, and it has not been shown to create the same levels of annoyance among nearby residents as more direct aircraft noise. Nevertheless, it is not included within

airport noise models, and, therefore, individual airports may have to deal with abatement or mitigation issues brought forward by their neighbors.

New noise management techniques continue to be developed. For example, aircraft are typically directed to descend into an airport in a series of steps, alternating between descent and level flying. This requires the use of flaps and slats on descent and occasional engine thrust to maintain altitude, both of which contribute to increased noise. The newly piloted continuous descent approach, as its name implies, brings aircraft in on a steady descent, which produces less noise than the traditional stair-step approach, especially for communities seven to 15 miles from the airport. This approach has been developed in the United Kingdom, and it is beginning to be tried elsewhere in Europe, with the potential of being tested in the United States in the future.

Although aircraft noise levels continue to decrease in response to regulation and innovation, noise continues to be a significant environmental problem for airport neighbors and, thus, an issue of concern to the global air travel system.

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See Also: Airport Planning; Airports, Environmental Issues and; Noise Pollution and Cars.

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Noise Pollution and Cars

Though not as frequently discussed as local air pollution or the transport sector's contribution to climate change, noise pollution constitutes one of the major social and environmental costs associated with traffic. This entry explains the nature of noise and how it is measured, summarizes factors determining the level of noise created on roads, and describes the main health effects of noise. The main regulations that address road traffic noise and its reduction in the United States and the European Union (EU) are mentioned. Noise abatement and noise from railways and aviation are not covered.

The Nature of Noise and How It Is Measured

Sound pressure from road traffic is measured in decibel A, or dB(A), which quantifies a logarithmic rather than linear scale. For example, 70 dB(A), about the average daytime sound pressure at the edge of a main road, is twice as loud as 60 dB(A), about the equivalent of a lively conversation. However, the actual definition of noise is highly subjective, and people generally consider any undesirable sound to be noise, irrespective of the dB(A). The threshold at which humans begin to experience physical pain lies at around 120 dB(A), reached or exceeded by the sound system at a rock concert or a referee's whistle, for example.

Noise is different from other vehicle emissions in that it is present only while its source is, so it must be quantified differently from other types of pollution. An equivalent sound level or L_{eq} is generally used to quantify community sound levels and to describe and compare noise at different time periods and locations. L_{eq} is constructed by averaging the total acoustic energy contained in the varying sound pressure levels measured over a certain period of time and denoting the L_{eq} as the dB(A) value equivalent to this average sound pressure. For example, $L_{eq}(h)$ describes the sound level equivalent that is reached during the noisiest hour of a day. This unit is commonly used in the United States for quantifying and regulating traffic noise.

The L_{eq} most frequently used in the EU are L_{night} for an eight-hour nighttime period, and L_{den} for a 24-hour period (day-evening-night). Weighting is applied to the evening and night components of L_{den} to account for the fact that the same sound levels are perceived as more disruptive in hours typically

devoted to resting or sleeping. The averaging carried out to create an L_{eq} can mask very different sound profiles, however. Several loud single sound incidents interspersed with quiet periods can result in the same L_{eq} value as more continuous but intermediate sound levels observed over the same time span, even though they would have different effects on sleep, for example.

Traffic noise is more often modeled than measured. This is a necessity if future noise levels need to be predicted, such as those associated with a planned road building project. Modeling is also generally used when existing noise levels need to be quantified for larger areas or over an entire road network. The resulting L_{eq} relate to outdoor environments, normally referencing a particular vertical and horizontal distance away from a road's center line. The actual noise levels experienced by people will diverge from the modeled L_{eq} , but using a standardized value allows meaningful comparison of traffic noise at different locations, or at the same locations but different points in time.

Noise From Road Traffic

Vehicle engine size and technology have a strong influence on traffic noise levels. However, when speeds of around 25 miles per hour (40 kilometers per hour) are exceeded, noise created by the aerodynamic drag of the vehicle and by tire friction on the road surface become louder than the engine sound. Road surface quality also influences sound levels; a smooth but porous surface is more effective at absorbing sound than a less porous and/or uneven surface.

Volume and composition of traffic also play an important role in determining sound levels. A single heavy-duty vehicle may generate a noise level equivalent to about 40 passenger cars. Increasing traffic volumes create higher sound levels, but changes in these metrics are relative to the ratio of traffic levels that are compared. Removing 2,000 vehicles from a road previously used by 4,000 vehicles per day decreases the L_{eq} for that road by a greater dB(A) value than adding the same 2,000 vehicles will increase the L_{eq} from a road previously used by 10,000 vehicles.

Because of the noise generated by braking and accelerating, vehicles traveling at varying speeds generate more noise than the same number of vehicles in smoothly flowing traffic, even if the average

speed remains constant. The cross-sectional profile of roads and adjacent buildings play a further role. Wider streets flanked by low buildings, possibly even with gaps in between (alleys, parking lots, etc.), lead to less reflected noise than narrow street canyons with closed frontages. However, the traffic noise audible behind such closed building fronts will be much lower than behind discontinuous structures.

The noise levels reaching individual receptors (that is, people) depend on their distance from the source—sound levels decrease proportionally to the square of the distance—and any barriers between them and the vehicles. These can include noise barriers along highways, vegetation, and buildings. It has even been shown that the same sound level is evaluated less negatively by people when its source cannot be seen. The noise level that is objectively created inside a building by traffic outside depends on the quality of the walls and windows, ventilation systems, and the acoustic properties of the rooms.

Health Effects of Noise

Noise levels above 120 dB(A) can cause acute pain, as well as temporary auditory impairments and even permanent hearing damage. At night, noise levels of around 40dB(A) generated by road traffic can cause sleep disturbance with associated short- and long-term effects, such as fatigue, deterioration in cognitive functions, and chronic disruption of sleep patterns.

Lower-level noise is also considered a nonspecific stressor, which results in adverse health impacts through the body's physical stress responses. These are partly determined genetically but are also modified by experience and environmental parameters, and, thus, have an important subjective element. The same measured sound levels can be differently perceived by different individuals, inducing different stress responses depending on the subject's evaluation of it (for example, music, construction noise, or the neighbor's leaf blower).

Physiological responses to noise stress include changes in blood pressure and heart rate, and increased release of stress hormones. Over prolonged periods of time, such stress responses can cause permanent functional changes in the body that are considered to be cardiovascular risk factors. Chronic noise stress is thought to be associated with an increased risk of hypertension (high

blood pressure) and ischemic heart disease, which is caused by reduced blood supply to the heart muscle. In 2011, the World Health Organization estimated that 800,000 disability-adjusted life years (DALYs), which are years that would otherwise have been lived healthily, are lost every year in the EU as a result of sleep disturbance caused by traffic noise.

Regulations Relating to Road Noise

The U.S. Code of Federal Regulations Part 772 details "Procedures for Abatement of Highway Traffic Noise and Construction Noise," which apply to all new highways, alterations to highways, or noise-abatement projects receiving federal aid or approval. The Federal Highway Administration's associated "Noise Abatement Criteria" define different noise levels that are acceptable for different types of land uses. For example, 67 dB(A) L_{eq} is allowed for residential areas, and 72 dB(A) around hotels, offices, and restaurants. It is important to realize that these limits only need to be considered in the planning of projects defined above. They do not need to take into account noise from other sources.

The EU's Environmental Noise Directive (2002/49/EC) stipulated that by mid-2013, strategic noise maps and related action plans were to be drawn up for agglomerations with more than 100,000 inhabitants, major roads used by more than 3 million vehicles per year, and major railway lines with more than 30,000 train passengers per year. These maps and plans must show the status quo and be reviewed every five years or when there is a new major development. Communities must take remedial action if certain L_{den} or L_{night} dB(A) values are exceeded.

The EU directive does not define these limits, though. It was left up to the member states to decide on them, a task that in some cases was delegated to the local planning authorities. In Germany, for example, the most commonly set upper acceptable thresholds are 54 dB(A) for L_{night} and 64 dB(A) for L_{den} . The EU directive also regulates comparable measures for noise from railways, airports, and industry, but the possible combined effects of these sources need not be considered together. Multiple exposures could therefore result in legal limits being breached without any official requirement for abatement measures.

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See Also: Highway Aesthetics; Neighborhood Disruption From Highway and Transit Construction and Operations; Noise Pollution and Airplanes; Traffic Noise Abatement.

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Noncommuter Travel

Noncommuter travel is travel for purposes other than going to work, such as for shopping or other household errands transporting children to and from school or activities (or in the case of older children, their transport of themselves); attending church and going to the gym; appointments with doctors, dentists, and salons; visiting family; and recreation.

These are rich areas for research, because while workers may have limited choices in terms of commuting travel behavior—beyond choosing a job, and choosing between different modes of travel such as driving alone, carpooling, walking, or using public transportation—people have much more control over their noncommuting travel behavior. This has especially been an area of interest since the 1960s or so, as the country became deeply suburbanized, reversing the century-old trend of increasing urbanization and creating a larger and larger populace dependent on driving.

For instance, a 2001 study of shopping patterns in Austin, Texas, found that drivers frequently chose more distant shopping destinations even when options local to their neighborhood were available to them. The study investigated the effectiveness of the frequent proposal that "urban-style" development planning, with decentralized commercial districts so that suburban neighborhoods have more

local shopping options, was a solution to suburban automobile overuse and overdependence. This study suggested that this solution would be ineffective, as factors other than distance and whether or not a car was needed impacted shoppers' choices. While consumers have experienced more fuel price volatility since that study, "big box" stores offering lower prices at the outskirts of town have become even more common.

This tendency to rely on cars even for shorter distance trips has been confirmed by the National Household Travel Survey (NHTS), which found in 2009 (the most recent survey) that 60 percent of trips under one mile were made by automobile. In many instances there may be little option but to drive even for such short trips—as some advocacy groups for greener travel have noted, not everyone has equal access to walking and bicycling, due to neighborhood layouts, safety features or lack thereof, and the presence or absence of sidewalks, paved shoulders, crosswalks, bike lanes, and bicycle storage facilities.

The growing interest in noncommute travel is reflected in the most recent NHTS survey, which added new questions pertaining to online purchases of delivered goods (which have a travel impact if they reduce shopping trips) and noncommuting employment-related travel, such as work-related travel for self-employed workers (the driving done by a self-employed plumber to a work site, for instance, or a craftsperson trips to pick up supplies and mail items).

Compared to the previous survey in 2001, the overall number of trips per driver and total vehicle miles both decreased slightly. These decreases were seen across various categories of noncommute trips. Social and recreational trips fell from 441 trips and 5,186 miles (annually) in 2001 to 436 trips and 4,842 miles in 2009 and "other" (which includes trips to church and to transport children) trips fell from 537 trips to 500, and 3,956 miles to 3,515 miles. While shopping-related vehicle miles fell from 3,062 to 2,979, shopping-related trips grew slightly from 459 to 468, though that amount is within the margin of error.

Travel was strongly correlated to income, though increases in noncommuting travel level off in the highest income brackets. More noncommuting travel is conducted by women than men, and the reverse is also true, though trips for school, church,

and recreation are roughly gender equal. The main difference is in family- and shopping-related trips, from picking children up at school, activities, or friends' houses, to taking them to the doctor or to have their hair cut, all of which types of travel are pronouncedly female dominated. The prevalence of women over men making family and shopping-related trips is the same as that of men over women for commuting trips, about 25 percent.

When broken down into destinations, "home" was the most popular (as it would need to be, as the endpoint for most return trips), while "shopping for groceries, clothes, or at the hardware store" was the only other destination to occur more frequently than the workplace. The next most popular destination, eating out, was less than half as common as the workplace.

In order of declining popularity, the remainder were dropping someone off, picking someone up, visiting friends or relatives, services (dry cleaner, post office, car service, bank), noncommuting work-related, gas station, other forms of shopping, the gym or sports, medical or dental services, church or religious activity, entertainment (including movie theaters, spectator sports, and bars), personal business/obligations, attending school, coffee/ice cream/snacks, unspecified social or recreational purpose, vacation or relaxation, nonwork meetings (homeowners associations, local government, PTA), personal services (hair, nails, salons), professional services (lawyers, accountants, tax prep), visiting public places like museums or libraries, pet-related trips, funerals and weddings, school-related library trips, and day care.

Though efforts have been made to increase participation in car pooling and to extend public transit coverage, the dominance of automobiles over other modes of travel for noncommuter purposes has been unchanged since 1990. The majority of public transit trips are work related, and driving accounted for 88.5 percent of all trips made in 2009, with walking a distant second.

But some cities have begun actively trying to change their residents' noncommuter travel behavior in ways other than just offering car pooling incentives. For instance, since the 1990s Portland, Oregon, has worked to expand the bikeability of the city by paving more shoulders and adding more bike lanes, and from 1991 to 2008 increased the bikeway miles of the city from 75

to 275. Ridership increased fivefold in the same period and has continued to increase since. Boulder, Colorado, has also worked to reduce car usage in the city by paving street shoulders and increasing sidewalk coverage (to increase pedestrian and bicycle travel), adding 380 miles of dedicated bike lanes or trails, and expanding and improving its public transit network. From 1990 to 2006, public transit trips nearly doubled, while driving declined and walking and bicycling increased.

In 2011, Boulder launched its bike-share program, with 100 bicycles distributed among a dozen bike-share stations. Users are allowed to purchase an annual, seven-day, or 24-hour pass for the program (available from kiosks publicly accessible 24 hours a day), entitling them to use a bicycle for up to one hour at a time for no additional fee. Additional fees accrue after that in order to encourage fast turnover.

The bicycle program is intended to be used less for recreational biking and more to replace other travel options, particularly car use. The flexibility of bicycling also frees some consumers from the necessity of car ownership, even if they live in an apartment or condominium without facilities to store their own bicycle. Bicycle and pedestrian travel are more likely in neighborhoods with "complete streets"—streets designed to accommodate all the forms of travel in their neighborhood, which means bicycle lanes or paved shoulders, sufficiently large and well-maintained sidewalks, frequent safe crossing opportunities, and, ideally, dedicated lanes for special vehicles such as buses in urban areas or tractors (which are wide and slow-moving enough to impede bike and foot traffic) in farming communities.

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See Also: Automobile Travel Patterns; Commuting; National Household Travel Survey; Travel Destinations.

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Nonmotorized Transportation

In many developed countries, walking and bicycling are not extensively used as a means of transportation, mainly attributable to societal attitudes toward walking and bicycling, sprawling development patterns, increased trip-chaining behavior, traffic safety and personal security considerations, and longer distances between residential locations and activity-participation locations.

Even in developing countries, where the nonmotorized share of trips has traditionally been much higher than in developed countries, there is a general trend of nonmotorized trips decreasing in share as a result of economic growth, the increased ability to purchase and use motorized vehicles, increasingly nonmixed land use patterns, and motorized vehicle ownership being viewed as a symbol of status and wealth.

The net result has been increasing urban traffic congestion in both developed and developing countries, with the concomitant consequences of air quality degradation, more inactivity and sedentary lifestyles in the population, and rapidly increasing greenhouse gas emissions with associated climate change effects. Projections suggest that the situation will only worsen over time unless sustainable

transportation options, such as the use of nonmotorized travel modes, becomes more prevalent.

In addition to planning and transportation professionals, the topic of nonmotorized travel, also referred to as "active transport," is gaining attention from health agencies. This is because physically inactive lifestyles pose significant health hazards. Specifically, insufficient physical activity has been identified as being among the leading causes of death and disability in the world. It is a serious risk factor for chronic physical and emotional diseases (such as coronary heart disease, stroke, some cancers, diabetes, and depression), which are among the leading causes of mortality. In addressing these health problems, health agencies around the world have identified active transport as a pivotal means to boost the levels of physical activity among individuals.

The societal problems associated with increasing motorized vehicle use and decreasing nonmotorized mode use has led many local, regional, state, national, and even international agencies to consider strategies to increase nonmotorized travel. At the same time, because the resources for funding transportation improvements are limited, planners and policy makers need to assess the potential usage and benefits of improvements in nonmotorized transportation against alternative transportation projects.

Such assessments require a good understanding of nonmotorized travel behavior to estimate the impact of policy actions aimed at encouraging bicycle and pedestrian travel. In contrast, evaluating the effects of bicycle and pedestrian infrastructure and programs on travel behavior and emissions is, in general, not (yet) a well-developed science. In particular, there is a need to identify and conceptualize the deterrents to nonmotorized mode use within the different contexts of developed and developing countries, as well as to pursue analyses to isolate and quantify the effects of these deterrents and corresponding countermeasures.

Challenges and Benefits

The deterrents to nonmotorized mode use in developed countries are generally assumed to include long trip distances resulting from sprawling land use patterns, increased trip chaining in a single sojourn from home or work, vulnerability to injury in the event of a crash with a vehicle, vulnerability to crime (an issue found particularly to

influence parents' decisions to allow their children to walk or bicycle to school), lack of shower and locker facilities at the workplace, a social perception that nonmotorized modes are uncomfortable or taxing, and a general social stigma against anything other than car use. The increasing deterrents to nonmotorized mode use in developing countries include the same considerations as those for developed countries, along with relatively poor nonmotorized mode infrastructure facilities.

Strategies to promote nonmotorized modes must address these deterrents, while also emphasizing the positive benefits of nonmotorized mode use at the personal level (such as better mental and physical health), the family level (potentially, lessened transportation expenditures and medical expenses, and more contact time with children and/or other family members), and society as a whole (less traffic

congestion and more social vibrancy). In particular, information campaigns can be an effective method of encouraging nonmotorized transportation and creating a culture of walking and bicycling.

For example, the GetAbout Columbia project in Columbia, Missouri, increased the proportion of residents who agree that the city is pedestrian- and bicycle-friendly from 66 percent to 80 percent in three years. Such attitudinal and perception changes can be important to shifting travel behavior.

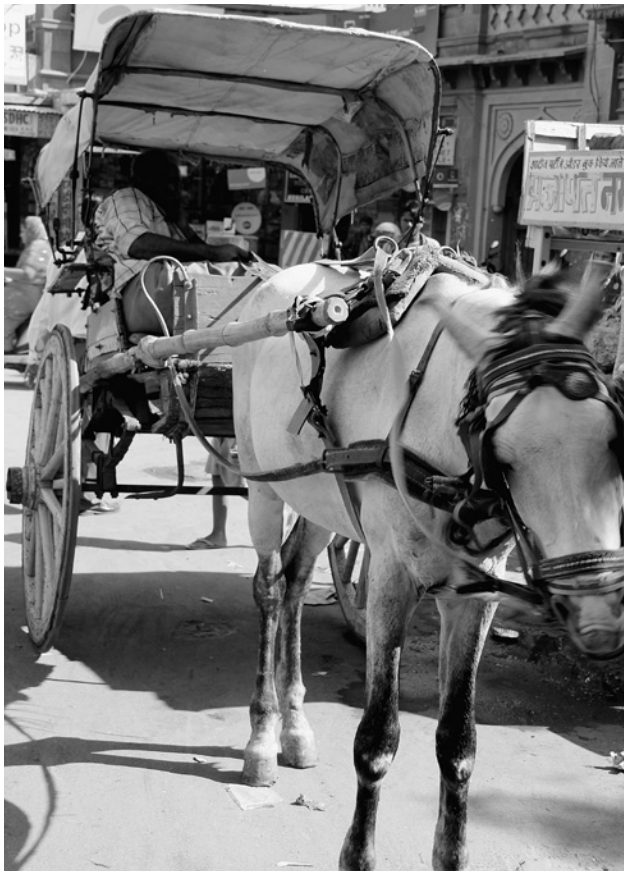
There also are a number of other promising ways to achieve the numerous benefits of nonmotorized transportation throughout both the developing and developed world. A variety of policy tools are available to planners and governments facing environmental and mobility-related challenges.

In developed countries, pricing strategies such as London's congestion charge can be effective in reducing automotive travel in city centers and encouraging residents to use a combination of nonmotorized and public transit options. In addition to such "sticks" to discourage the use of personal motorized forms of travel, "carrots" can be offered for the use of nonmotorized modes in the form of subsidies associated with public transportation use and/or health insurance premium reductions based on the amount of nonmotorized mode use.

In developing countries, promoting nonmotorized travel over the personal automobile will require an attempt to challenge the widely held view that owning a car equates to personal success and freedom. Local authorities everywhere can develop more dense, mixed-use developments, which can encourage nonmotorized travel and promote more active lifestyles.

It is also critical that researchers continue to investigate factors that affect nonmotorized-travel behavior and the effectiveness of associated policies. As policy makers work to integrate nonmotorized travel into their transportation systems and planners pay more attention to the effects of land use on travel behavior, researchers must continue to investigate how, why, and to what extent these new policies are effective in providing safe and reliable transportation to all travelers.

In addition to evaluating existing policies, research should also investigate new possible avenues for facilitating nonmotorized travel, thus providing innovative solutions to both old and new transportation problems. As always, studies must



A horse-drawn vehicle is a mechanized piece of equipment with either two or four wheels pulled by one or more horses. In developing nations like India, horses, llamas, oxen, donkeys, and even dogs remain important modes of transport.

explore the effects of transportation policies on the health and safety of both the public and the environment.

As countries, cities, and towns throughout the world work toward improving the way their transportation systems serve their residents, promoting nonmotorized travel presents an attractive option to relieve congestion, improve public health, and reduce emissions of pollutants.

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See Also: Bicycles; Mixed-Mode Transit Systems; Nonmotorized Vehicles, Safety Issues of; Pedestrian Travel; Pedestrian-Friendly Design; Travel by Mode; Trip Chaining; Walking.

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Nonmotorized Vehicles, Safety Issues of

Nonmotorized vehicles are vulnerable to a broad array of hazards to which motorized vehicles are not generally susceptible. Safety issues for users of nonmotorized vehicles fall into several different areas of concern. These include behavior, infrastructure, education, enforcement, and the physics of reducing injury and death. This entry also addresses hazards, vulnerabilities, and some methods to improve safety.

Definitions

Several definitions are pertinent to the issue of safety in relation to nonmotorized vehicles:

Nonmotorized vehicles. These are vehicles that are powered by human energy, including bicycles, unicycles, tricycles, scooters, skateboards, roller skates, inline skates, roller skis, wheelchairs, and other human-powered vehicles. It is important to note that while their devices are not classified as nonmotorized vehicles, users of motorized wheelchairs, mobility scooters, electric-assist bicycles, and various gas-powered scooters and skateboards often share the same challenges that nonmotorized vehicle users experience in regard to limited facilities and vulnerabilities to larger, heavier, and faster vehicles.

Active safety measures. These are actions taken to protect nonmotorists. While traveling on a nonmotorized vehicle, the following principles are essential elements of crash prevention: control the vehicle, follow the rules of the road and know traffic law, be visible, be predictable, use good lane positioning, signal your intentions, pay close attention to other road users and road hazards, learn to watch for and avoid other drivers' mistakes, and allow buffers of space in all directions for slowing, stopping, and maneuvering.

Collision. A collision is an impact caused by two or more moving vehicles or bodies coming into contact and exerting force upon each other.

Crash. When a bicycle rider loses control and impacts a stationary object or falls from the bicycle. A collision is a type of a crash, but not all crashes are collisions.

Nonmotorist. This is the user of a nonmotorized vehicle.

Passive safety measures. These are not actions per se but include protective equipment such as helmets, gloves, wrist guards, pads, body armor, and eye protection.

Rights and Responsibilities of Operators

In the United States, bicycle riders are differentiated legally from users of other nonmotorized vehicles in that they are classified as vehicle

operators. So, they are granted all the rights and responsibilities of drivers of motorized vehicles when they travel on roadways. In all 50 U.S. states and the District of Columbia, bicycles are either (1) defined as vehicles or (2) granted all the general rights and duties of drivers of vehicles when they are traveling on roadways.

It is important to be familiar with the legal rights and responsibilities of all road users in the locales where one travels. In addition to bicycles, other nonmotorized vehicles may be regulated by state, county, or local jurisdictions. It is best to check your state and local laws and to be familiar with your rights and responsibilities as a nonmotorist. In some jurisdictions, nonmotorized vehicles may be restricted to sidewalk use (requiring slow-speed travel and yielding to pedestrians), restricted from sidewalk use, banned altogether, or left unregulated.

While bicycles are often clearly regulated and may have dedicated facilities, other nonmotorized vehicles may face a greater legal and practical ambiguity when it comes to defining safe operation. This ambiguity is itself a hazard; if nonmotorists do not understand their role in traffic, risky behaviors are more likely. This is not an exhaustive treatment of nonmotorists' vulnerabilities, but one of the most common hazards and vulnerabilities of nonmotorists is that of speeding motor vehicles.

Education and Enforcement

Many nonmotorized road users are not aware of the laws that apply to them; nor are they aware of the legal rights and responsibilities of other road users. Many risky behaviors on the part of all classes of road users have become normalized; these commonly include speeding, failure to yield, and failure to stop. To improve the safety practices



A woman and child transport multiple bags and packages in New York City's Central Park while using two different types of nonmotorized vehicles: a bicycle and a kick scooter. Helmets, gloves, eye protection, and pads are recommended for users of nonmotorized vehicles, which may have additional vulnerabilities because of small wheels and a lack of brakes.

of road users requires the education of all users about their rights and responsibilities, as well as the impacts of risky behaviors. Education is best supported by a visible increase in even-handed enforcement practices.

Effects of Changing Technology

Electric and hybrid cars present special threats to nonmotorized travelers because they are so much quieter than automobiles powered solely by internal combustion engines. Users of nonmotorized vehicles rely heavily on their hearing, and the lack of engine noise of hybrid and electric cars make it more difficult to hear an approaching vehicle.

Higher collision rates between hybrid cars and bicycles have been observed than between bicycles and conventional autos. Although one study only looked at bicycle collisions, this is a hazard for all nonmotorized modes of travel, including walking.

Hazards

There are many dangers to nonmotorists, both stationary and moving hazards. Stationary hazards include broken pavement, potholes and longitudinal seams in the road surface; metal fixtures in the roadway (for example, drain grates and manhole covers); debris such as broken glass, sand, gravel, pavement chunks, tire retreads, litter, and leaves; fragmented networks of facilities for users of nonmotorized vehicles; and confusing and inadequate facilities, which may inspire risky behavior.

Moving hazards can include speeding, aggressive, distracted, and inattentive road users of all modes (including other nonmotorists); dogs and other animals; pedestrians; and doors opening from stationary vehicles. Stationary hazards can be relatively easy to avoid, while moving hazards can be more challenging. This is only a partial list, and there are often additional hazards that are locally specific.

Each of these hazards, combined with the nonmotorists' own vulnerabilities or weaknesses, poses risks to the individual rider of a nonmotorized vehicle. The nonmotorist can employ many practices, however, to reduce that risk. For example, riders are only vulnerable to the hazard of the door zone if they ride there.

Riding skills, along with equipment type and condition, play a big part in the performance of a nonmotorist in relation to hazards and rough

conditions. A rider's accurate self-assessment of skill and equipment is also of crucial importance to safe operation of any vehicle, but especially a nonmotorized vehicle.

Critical thinking, good judgment, and experience each contribute to safe operation. If conditions are especially hazardous, it is best to slow down, stop, or find a different route. While it is important to know the relevant legal frameworks where and when one rides, prudence dictates that nonmotorists err on the side of being conservative; having a legal right on a road does not mean that a person will be able to survive a hazardous situation unscathed.

Vulnerabilities

Nonmotorists have many vulnerabilities, some that are particular to the specific mode and some that are general. Generally, nonmotorists are vulnerable in that they are not enclosed within their vehicle, making them as exposed as a pedestrian, even though they may travel much faster than pedestrian speed. Nonmotorists are generally not well accommodated, expected, or respected on the roadway, and they tend to move more slowly than motorized vehicles. As with any travel mode, nonmotorists are sometimes unable to control their vehicle, and they fall or crash. Learning to control one's vehicle and safely maneuver it is the foundation of active safety, and a way to reduce or eliminate operator-caused crashes.

The particular vulnerabilities of nonmotorized vehicles are largely based on the wheel size and type, as well as the inclusion, or not, of brakes. Except for bicycles, nonmotorized vehicles generally have small-diameter wheels. Smaller wheels have a more difficult time rolling over obstacles than a larger wheel would have rolling over the same obstacle. Potholes, curbs, gutters, drain grates, manhole covers, and other road hazards present greater danger to smaller-wheeled vehicles than to their larger-wheeled counterparts.

Skateboards, roller skates, inline skates, compact kick scooters, and roller skis all have small-diameter solid wheels with a small contact patch. As opposed to the pneumatic tire of a bicycle, these wheels are generally made of solid urethane. These vehicles and some other nonmotorized vehicles do not have brakes, which makes emergency stops much more difficult and hazardous. Evasive maneuvers also can be more difficult with smaller solid wheels.

Nonmotorized vehicles with pneumatic tires and larger-diameter wheels are easier to manage on rough pavement and in variable conditions than small solid-wheeled vehicles. Kick scooters and other small-wheeled vehicles such as baby carriages, prams, and strollers may have either solid rubber tires or pneumatic tires, but the wheels generally have a much smaller diameter than bicycle wheels. These types of vehicles may or may not have brakes.

Running strollers are designed for higher-speed travel on uneven surfaces and, therefore, fare better than the typical carriage or stroller in challenging conditions. Electric mobility scooters also have small-diameter wheels, either solid rubber or pneumatic, and are subject to many of the same challenges as other small-wheeled vehicles. Motorized and nonmotorized wheel chairs typically have small front wheels and larger rear wheels.

Impact Speed

The speed of an object at the moment of impact is one of the primary variables that determines how much force is applied upon impact. Studies of automobile–pedestrian collisions consistently reveal that pedestrian injury and death rates increase at higher-speed impacts. In fact, there is a nonlinear increase in the risk of injury or death to the pedestrian at increased impact speeds. Nonmotorists are as vulnerable to automobile crashes as pedestrians, and, by extension, higher-speed traffic presents a greater threat to users of nonmotorized vehicles.

Variables That Improve Safety

There is safety in numbers; nonmotorists broadly and bicycle riders in particular are safer when there are more of them on the road. A number of studies point to increases in road safety as the number of bicycle riders increases.

When an individual is riding alone, he or she can follow best practices for active and passive safety. This means an individual can largely avoid or mitigate most hazards and vulnerabilities. Active safety includes maintaining control of the vehicle,

remaining visible, being predictable, following the rules of the road and traffic laws, using lane positioning and signaling to communicate movements and discourage others' mistakes, paying close attention to other road users and road hazards, learning to watch for and avoid other drivers' mistakes, and allowing buffers of space in all directions for slowing, stopping, and maneuvering.

Nonmotorists are advised to wear the appropriate safety equipment, including helmet, gloves, eye protection, and pads. Users of nonmotorized vehicles should familiarize themselves with the active and passive safety measures that are appropriate for the mode they are using. Motorists, meanwhile, can play an important role in improving safety for nonmotorists by looking for and expecting nonmotorists, yielding appropriately, passing safely, and being patient with some slowing of traffic.

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See Also: Bicycle Commuting; Bicycle Safety; Bikeways/ Bike Lanes, Road Design Issues of; Pedestrian Safety.

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Ocean Cruise Industry

Cruising is a luxury shipboard vacation in which passengers enjoy onboard amenities punctuated by visits to a series of exotic ports of call; it is about the journey, not the destination. Cruising is an alternative to resort vacations, but in total, cruise ships constitute less than 1 percent of worldwide hotel beds. However, cruising is growing in popularity, especially among North Americans, with an estimated 20.9 million passengers in 2013, a 3.3 percent increase over 2012. As a form of tourism, cruising has both positive and negative economic, sociocultural, and environmental impacts and poses some unique challenges in assuring the safety of passengers.

Cruise Lines and Ships

The cruise industry is highly concentrated, with the four largest cruise companies (Carnival, Royal Caribbean, Norwegian Cruise Line, and MSC Cruises) accounting for 96 percent of all passengers. The “big four” cruise companies are horizontally integrated with a variety of cruise lines, each of which is branded to serve a different market segment. Carnival is the largest operator, with nearly half of all passenger cruise lines that include Costa Cruises, Princess, Holland America, Cunard, and P&O.

The corporate concentration of the cruise companies reflects the capital-intensive character of the

industry. The first generation of cruise ships in the 1970s carried about 1,000 passengers, but the drive to accommodate more passengers and increase onboard revenues has emphasized economies of scale: larger ships and more elaborate onboard facilities. Most contemporary cruise ships carry between 2,000 and 4,000 passengers.

Most new cruise ships are built in Europe by shipyards experienced in the design and construction of cruise vessels, such as Fincantieri, STX Europe, and Meyer Werft. Cruise ship construction occurs in cycles, with several ships ordered, built, and entering the market within a short time. The biggest cruise ships afloat today, Royal Caribbean’s *Allure of the Seas* (2010) and *Oasis of the Seas* (2009), weigh 220,000 gross tons, cost about \$1.24 billion each, and took about four years to be delivered. They carry up to 6,300 passengers, with a crew of 2,700. Mega-liners such as these are floating resorts offering live entertainment, casinos, movie theaters, art galleries, shopping malls, skating rinks, rock climbing walls, golf simulators, multiple swimming pools, spas, health centers, exercise facilities, business and conference centers, and multiple dining venues. Countering the trend to larger ships, a tiny but growing cruising niche revolves around small vessels—yachts, rugged expedition ships, and classic schooners—where passenger counts can be as few as 10 and rarely exceed 200. These ships serve a more exclusive market segment focused on luxury,

personal service, and unique experiences such as visiting Antarctica, sailing a schooner around small Caribbean islands, or cruising European rivers.

Passengers and Profits

The United States is the world's largest cruise market, making up two-thirds of the global market. Cruise passengers are getting younger (average 46 years of age), with above-average (\$93,000) annual household income. Three-quarters of passengers are married and travel as couples; 16 percent bring children. Surveys of passengers suggest that food, family time, warm weather, relaxation, and romance are the most valued aspects of cruising. Moving away from traditions such as assigned dining times, seating, and dress codes, freestyle cruising has proven popular. Themed cruises that focus on music, dance, food, wine, or health, or distinctive market segments such as gay and lesbian customers, are another way cruise lines differentiate to attract passengers.

Ninety percent of cruises are booked through travel agents, and cruises constitute more than half of all travel agent vacation sales. What is novel with cruising is that the ship itself is the destination, which creates a captive market for onboard goods and services as well as shore-based activities, especially at facilities owned by the cruise line. The average passenger spends about \$1,700 for the cruise, including onboard and off-ship expenses. Onboard services account for between 20 and 30 percent of total cruise line revenues. Passengers spend an average \$100 per port of call, with three to five ports on a typical seven-day cruise.

Many cruise lines offer low-cost packages to boost passenger volumes, but premium options such as luxury suites and deluxe dining have greater profit margins. With a premium suite costing five times as much as a stateroom, these options effectively re-create the class system of 20th-century ocean liners.

Ports and Itineraries

The standard cruise itinerary is a loop beginning and ending at a hub port with the ship disembarking passengers in the morning and embarking new passengers the same afternoon. Hub ports must be accessible to a large customer market by a well-connected airport with significant airlift capacity and should themselves be tourist destinations (e.g.,

Miami, Barcelona). Larger cruise ships may use a fixed-base hub port and cruise the same region year-round, as *Allure of the Seas* does from Fort Lauderdale to the Caribbean.

About half of cruises last seven days; longer cruises have lower profit margins because passengers spend less as the cruise progresses. In developing itineraries, cruise lines focus on maximizing revenue, weighing passenger factors (seasonal demand, optimal cruise length, sailing time versus shore time, and "must see" destinations) against operational factors such as berthing capacity and nautical accessibility of ports and distance between ports (cruise ships can cover 200 nautical miles per night). Since cruise ships tend to have shallow drafts, the criteria for cruise ports differ from commercial ports; cruise ships are also able to anchor and use tendering services. Cruise ports tend to be near either city centers with cultural amenities or natural amenities such as beaches.

Climate is an important factor in itineraries. In the Northern Hemisphere, Baltic, Norwegian, Alaskan, and New England/Atlantic Canada cruises operate only in summer, while South American and Australian/New Zealand cruises operate only in winter (which is summer in the Southern Hemisphere). North America is the dominant embarkation region year-round; during summer, Europe accounts for 40 to 50 percent of embarkations. The Caribbean has long been the main cruise market and operates year-round with a summer low season. The Mediterranean also operates year-round with a winter low season. Together, these two regions comprise more than 70 percent of global cruising capacity. Repositioning itineraries are offered when ships move between seasonal markets and itineraries.

Impacts of Cruising

The U.S. cruise industry generates more than 450,000 jobs with \$15 billion in wages and billions more in the purchase of goods and services while also providing local revenues at the ports visited by its ships. The benefits of cruising for ports of call have been debated. When passengers are ashore for only a few hours on excursions planned by their cruise line, their experience of a destination may be a kind of constructed fantasy that is an extension of their ship, leaving them with little real insight into the destination and providing limited local economic benefit.



Three cruise ships, including Princess Cruises' Star Princess (950 feet), Holland America's Zuiderdam (955 feet), and Westerdam (936 feet) are berthed in the Port of San Diego, October 4, 2012. At left is the decommissioned aircraft carrier U.S.S. Midway, which was the largest ship in the world (at 972 feet) until 1955; it has served as a naval aviation museum since 2004.

According to the International Transport Workers Federation, cruise ship workers are underpaid, have poor working conditions, limited leisure time, unsatisfactory accommodation, and few rights. The ethnic diversity among crew combined with a top-down marine industry management style can make it difficult for crew to improve their situation.

Cruise ships make up less than 1 percent of the global merchant fleet, yet it has been estimated that they are responsible for 25 percent of all waste generated by merchant vessels. Cruising cannot be considered a sustainable form of tourism because cruise ships consume significant resources and ships and passengers have environmental impacts on their destinations, especially in "ecologically vulnerable" regions (for example, Alaska or the Caribbean). Cruise lines have, however, adopted more environmentally sensitive practices and onboard waste disposal, recycling, and sewage treatment technologies to reduce their environmental impact. With these measures, the cruise industry claims to be approaching "zero discharge."

Passenger and vessel safety has received more attention recently, especially after the *Costa*

Concordia tragedy left 32 dead in January 2012. Of all travel industries, cruising is the least governed by national regulations. Companies register their vessels where the costs are lowest and the oversight and requirements are fewest; most of today's cruise ships are registered in the Bahamas, Bermuda, or Panama. Once a ship travels beyond 200 nautical miles from shore, it is regulated by the International Maritime Organization (IMO) and its flag country. The IMO lacks the authority to enforce its own guidelines and is unable to impose fines or sanctions on cruise lines that do not meet Safety of Life at Sea recommendations, and the flag states rarely enforce them. The U.S. Coast Guard conducts annual Certificate of Compliance inspections as well as announced and unannounced inspections of every cruise ship embarking passengers in U.S. ports to ensure the vessel meets all international conventions and domestic requirements for safety, security, and environmental protection.

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See Also: International Waters; Marine Transportation System; Ocean Passenger Travel; Recreational Travel; Ships; Tourism; Travel by Households; Travel Choice; Travel Demand; Travel Destinations.

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Ocean Passenger Travel

Ocean passenger travel is performed principally by passenger ships, a category of merchant ship, although a small amount of passenger travel is done on cargo ships, which sometimes offer a small number of passenger accommodations. Before air travel became more widespread, these ships, most of which carried fewer than 20 passengers, were a common method of travel. Most ships that carry passengers on the ocean today are ocean liners, cruise ships, or ferries.

Ferries typically take passengers (and sometimes vehicles) only on brief trips, especially of commuting or "water taxi" distance. When ocean travel is involved, ferries will usually go only so far as a nearby island, or from one part of the shore to another. That said, ferry service is also offered from southeast Alaska to Bellingham, Washington, which takes at least a day.

In recent years, the ocean passenger travel industry, which in the United States serves about 10 million people a year, has shifted in favor of larger ships, lower fares, and departures from more ports (so that fewer passengers need to arrange travel to the port of departure). Nearly half of passenger ships depart from three Florida ports: Miami, Port Canaveral, and Fort Lauderdale. This is in part due to the climate, but also because Florida's chamber of commerce and legislature have long incentivized travel and tourism businesses to operate in their state.

In general, smaller ships have been relocated to overseas operations in favor of larger vessels in

the United States. For instance, Royal Caribbean's *Oasis of the Seas*, launched in 2009, has a capacity of 6,000 passengers, the size of a small suburb. Larger vessels have made the work of passenger security screening at passenger terminals more difficult, while also taxing the infrastructure of those facilities. The Maritime Transportation Security Act of 2002, passed in response to the terrorist attacks of September 11, 2001, requires all passengers and luggage to be screened by metal detectors and X-ray scanners when those passengers are embarking or disembarking.

Since 2012, cruise lines have been required by an industry-adopted safety policy to conduct passenger safety drills before leaving port. This was adopted in response to the January 2012 *Costa Concordia* disaster in which the cruise ship crashed into rocks near the shore of the island of Giglio off the western coast of Italy, resulting in dozens of deaths and missing persons. About one-fifth of the ship's passengers had not attended the ship's safety drill, which had been conducted before they had boarded.

Passenger Travel Becomes Specialized

Passenger freighter travel does still exist and is preferred by some travelers because the ships are less crowded and lack the same culture and atmosphere as cruise ships. It is also more common in some parts of the world than others. Freighter travel is the principal mode of passenger ocean travel on the Caspian and Black Seas, for instance, and is common throughout much of the third world, where maritime trade is common.

Today, if there is no ship's doctor aboard, international regulations limit the passenger count to 12. There are significant drawbacks to freighter travel; passenger service is often an afterthought, and schedules can change at a moment's notice because of conditions that are related to the transport of the ship's freight. Food is not always provided, and arrival times at the final destination are often unpredictable. Usually passengers are given a small cabin and eat alongside the crew in the mess hall. They may also be given access to other crew common areas. Not all passenger cabins have their own bathroom.

Standards of what passengers can expect vary according to the country in which the freighter is registered. That said, freighter travel also offers



Guests enjoy the swimming pool on the German-built AIDAvita cruise ship, part of the British AIDA Cruises company fleet. The AIDAvita can carry up to 1,266 passengers and 426 crew, far fewer than many of the newest ships operating in the United States. The U.S. ocean passenger travel industry caters to about 10 million people a year, with some of the very largest ships, such as Royal Caribbean's Oasis of the Seas and its sister ship, Allure of the Seas, carrying upward of 6,000 passengers at a time.

unique trips that the cruise industry may not, including the aforementioned Caspian Sea, or a trip from the Great Lakes to western Europe. Further, if food or drink is made available for sale, it is considerably cheaper than on cruise ships, because it is an insignificant source of revenue for the freighter. Freighter travel is also often available from smaller ports than cruise ships, which tend to leave from major hubs. However, the security measures adopted since September 11, 2001, have reduced the number of smaller freighters accepting passengers to or from the United States.

Freight, however, can travel on passenger ships, which, with the exception of cruise ships, usually include a freight hold. Ocean liners carried equipment for freight handling, but today this is true only of the older ships in the fleet, and the capability often goes unused.

Crews of merchant ships, including all passenger ships and freighters, are members of the merchant marine. The U.S. merchant marine consists of the crews of the merchant ships owned by U.S. citizens and registered in the United States. Other crews, including on ships owned by American businesses but registered overseas, may be members of the merchant marine of other countries.

During wartime, the merchant marine is considered an auxiliary service to the navy and may be pressed into service to transport troops or supplies, but it has no combat role. Merchant seamen are not military personnel, although they may use ranks similar to those of the military, including captain, mate, and other titles.

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See Also: Ferries; Inland Waterways, Passenger Traffic and; International Waters; Marine Transportation System; Maritime Administration; Ocean Cruise Industry; Ships.

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Origin–Destination Models

An origin–destination (OD) model is fundamental to understanding travelers' flow pattern for any specific transportation or region. The model has been widely used to understand characteristics of travel demand. The results can be used for transportation demand management, planning, and policy. This introduction to OD models covers its definition, data, methods, and applications.

Definition

The OD model can be defined as a way to represent the flow of travelers between their origin and destination for any specific transportation mode or region. The major difficulty of OD modeling is obtaining accurate estimation to represent these flows in origin-to-destination tables. Thus, the OD model is the basis of trip distribution, destination choice, or zonal interchange analysis, which is the second step in the four-step transportation forecasting model. Information on trip distribution is presented in a two-dimensional square OD matrix denoting volume of demand flows. Depending on the specific research

purpose, trip distribution of an OD table can be represented by numbers of trips, numbers of passengers or freight volumes, or numbers of traffic counts.

Data

To estimate OD demand is a challenging and costly task because it requires a large amount of OD-specific data. Data can be obtained in different ways, ranging from a large-sample OD survey and traffic monitoring system to physical road counters. The monitoring system, sometimes also called an automatic vehicle identification system, collects OD information of vehicles through two or more cameras placed separately at certain distances, or by local street sensors or monitoring cell phone signal (CPS) movement and distribution.

The OD information of each vehicle can be identified through vehicle plate recognition. In addition, vehicle information such as travel time and distance can be automatically calculated based on the information recorded by cameras or cell phones. In recent decades, because of the development of Intelligent Transportation System (ITS), traffic data can be obtained in a much more timely and efficient manner. Traffic counts can be observed at very short time intervals by traffic monitoring systems. This information can then be used for time-dependent OD modeling.

Despite the use of both surveys and the advanced traffic monitoring system, which provide solutions for OD data collection, the financial constraints of using a sampling survey and traffic monitoring system still prohibit collecting data for the whole population. In order to complete the OD matrix of the population, some mathematic algorithms are developed to estimate missing data.

Methods

Classic transportation forecast modeling is conducted in four steps: trip generation, trip distribution, mode choice, and traffic assignment. The OD model is used at the second step to generate information on trip distribution in the form of trip tables.

The OD table is the central goal of OD modeling because it displays the distributions of trips going from origins to destinations. The conceptual framework of an OD table is illustrated in Table 1. The table is an $n \times n$ matrix. The row of the table represents place of origin, while the column represents place of destination. Each cell in the table indicates

the numbers of trips or passengers from origin i to destination j . The task of OD modeling is to fill in the cells for the tables headed 1 to n .

Theoretically, OD data can be obtained through an OD travel survey or collections from traffic monitoring systems. In reality, it is normally impossible to fill the whole OD table with the collected data as travel surveys, while the traffic monitoring system is only able to provide sample data instead of the whole data population. Therefore, to complete the whole OD matrix, it becomes necessary to fill all the blank cells using estimation approaches. Further forecasts are built on the estimation of potential flows from land uses that do not yet exist but need to be planned for in terms of infrastructure support for future need.

The basic rationale for OD estimation is to find the relationship between the missing data and the sample data based on traffic counts. Assuming the traffic-counts data is collected from a roadside survey, the expected OD link flow D_n is the missing data that needs to be estimated. It can be expressed in equation (1):

$$D_n = k \in K p_{kn} T_k \quad n \in N \quad (1)$$

where p_{kn} denotes the proportion of OD trip pair $k \in K$ through the link n , and T_k denotes the total number of OD trip pair $k \in K$, which is given in the sample data.

In order to achieve a unique solution for the equation, additional information between the estimates and sampled data is needed and should be specified. There are plenty of techniques to build this linkage, such as the Fratar (growth) approach, intervening opportunities, neural network, gravity/spatial interaction approach, and entropy estimation. Each approach provides a unique mathematic algorithm for data estimation.

In this introduction, the four most widely used OD forecasting methods are presented: the gravity/spatial interaction approach, the entropy approach, the equilibrium approach, and the dynamic OD estimation.

Gravity/Spatial Interaction Approach

The gravity/spatial interaction approach illustrates the macroscopic relationships between places (such as home and working place). The method is often used to model interactions between the trip matrix and related parameters, such as distance, time, cost, and other activities associated with each location. The basic gravity approach for estimating an OD matrix based on trip distribution data can be expressed in equation (2):

$$D_{ij} = i_j O_i D_j A_i B_j f_{ij} p_{ij} \quad (2)$$

where D_{ij} represents the flows in particular link from i to j . O_i and D_j are the trips produced from zone i and attracted by zone j respectively, and f_{ij} denotes a deterrence function; p_{ij} is the proportion of trips traveling from zone i to zone j . A_i and B_j represent the balancing factors.

The estimation can be conducted using nonlinear least-square regression, weighted nonlinear least-square regression, or maximum likelihood estimation. Applications of gravity approach to OD estimation are extensive. For example, Pierre Robillard from University of Montreal, Canada, and Per Högborg from University of Göteborg, Sweden, have adopted the gravity approach to achieve OD matrix estimation based on data of traffic counts.

However, the gravity approach has a critical disadvantage. The estimation is not inclusively accurate when “external” or “through” trips are included in the analysis. Although the origins or destinations (or both) of these trips are outside the area of interest, they are usually unnecessarily combined or included in analysis. As a result, travel demand for each OD pair may be overestimated if these external trips are not separated out.

Entropy Approach

Alan Wilson from University College London, developed another algorithm for transportation OD matrix estimation. The algorithm is known as the “entropy approach.” The concept of entropy originates in thermodynamics, which is mathematically

Table 1 Origin-destination table

Origin	Destination			
	1	2	3	n
1				
2				
3				
n				

defined to account for the flow of energy through an energy process.

In its later development in statistics, entropy is defined as “a measure of the loss of information in a transmitted message.” The entropy approach includes two categories of methods: the entropy information minimization approach and the entropy maximization approach.

The entropy maximizing procedure analyzes the available information to obtain a unique probability distribution of OD trips. Assume a set of origin zones, labeled i , and a set of destination zones, labeled j , and let D_{ij} be the matrix of flows from i to j . The traditional gravity model can be written as equation (2). The problem with this model is that the predicted D_{ij} does not satisfy

$$jD_{ij} = O_i \quad (3)$$

where j represents the sum over all destination zones, and

$$iD_{ij} = D_i \quad (4)$$

The number of possible combinations for trip distribution can be described in equation (5):

$$W = D! / i! j! \quad (5)$$

where D represents the total numbers of trips and ij is the product over all i and j , and $!$ represents “factorial.” The number of combinations associated with a particular OD matrix D_{ij} can be taken as the probability that the given D_{ij} occurs. In addition, the constraints of trip distribution can be written as

$$ijD_{ij}f_{ij} = F \quad (6)$$

where F is assumed to be the total transportation deterrence constraints (measured either by time cost or expenditure) and the sum is over all i and j . The most probable state can be found by maximizing W in equation (5), subject to equations (3), (4), and (6). According to Wilson’s approximation approach, W can be transformed to the form

$$W = -ijD_{ij}\log(D_{ij}) \quad (7)$$

which can be recognized as a form of entropy, yielding the notion of the “entropy maximizing models.”

In the circumstance where additional information besides traffic counts is available, the information entropy minimizing approach can be applied for the estimation. Two other scholars, Henk J. Van Zuylen and Luis G. Willumsen, have made great contributions to develop this method.

However, as pointed out by Sharmintha Bera and K. V. Krishna Rao from the Indian Institute of Technology, Bombay, both the entropy information minimization approach and the entropy maximization approach have the disadvantage of not considering the uncertainties in traffic counts and prior matrix, which they believe can be erroneous and can influence the estimation output.

Equilibrium Approach

Both the gravity approach and the entropy approach are early techniques of OD modeling that relied on the assumption that travel time is invariant among all transportation networks. However, in the real world, travel time varies significantly depending on the severity of road congestion, especially in urban areas and networks operating near capacity. To remedy this estimation drawback, the “equilibrium” or “combined” solutions were developed, which consider the influence of congestion in the form of feedback effects. Sang Nguyen, Mark Turnquist, and Yehuda J. Gur are the contributors to the algorithms of OD estimation under equilibrium assignment.

The equilibrium assignment approach assumes the knowledge of the travel costs between each OD pair. This relationship can be represented, as Nguyen and Willumsen have done, by:

$$\text{Min } FV_{lm}, T_{ij} = lm0V_{lm}clmxdx - ijcijT_{ij} \quad (8)$$

Subject to

$$\begin{aligned} T_{ij} - rT_{ijr} &= 0 \quad \text{for all } i, j \\ T_{ijr} &\geq 0 \quad \text{for all } i, j, r \\ T_{ij} &\geq 0 \quad \text{for all } i, j \\ V_{lm} &= ijT_{ijr}\delta_{ijrlm} \quad \text{for all links} \end{aligned}$$

where clm is the cost-flow relationship for link lm , and cij denotes the observed cost of traveling between i and j . T_{ijr} is the number of trips between i and j via route r . δ_{ijrlm} equals 1 if route r between i and j uses link lm ; otherwise, it equals 0.

As noted by Nguyen, this equation has the same structure as the traffic assignment model with elastic

demand. He suggested an algorithm for its solution that starts with an OD matrix, and provided adjustments to create a convergence. His problem has a unique solution in link volumes but not in the OD matrix. As a result, this solution is consistent with equilibrium assignments and observed flows.

Dynamic OD Estimation

The aforementioned OD demand estimation considers the trip distribution in a static scenario. The problem with such a static model is that it does not include the time character of traffic flow dynamics. It assumes that the observed flows are in a steady-state situation. Recently, there has been an increasing interest in developing dynamic OD estimation methods for transportation forecasting and planning.

The dynamic OD estimation also refers to a time-dependent OD demand estimation. It differs significantly from the static OD demand estimation in that the target demand table is estimated based on historical OD demand data and other archived traffic information, which is able to capture network system dynamics. There are several approaches for dynamic OD estimations, such as the state-space modeling, Kalman filtering approach, and two-stage demand estimation. Kalidas Ashok and Moshe Ben-Akiva from Massachusetts Institute of Technology and Xuesong Zhou and Hani S. Mahmassani, from University of Maryland at College Park have made substantial contributions to expanding the applications of dynamic OD estimation.

Applications

One of the major applications of OD modeling is to understand travelers' true origins and destinations for any specific mode, city, or region. It can be used to analyze travel demand and traffic volume distribution. Take aviation, for example. On a flight from Washington Dulles International Airport to Chicago O'Hare International Airport there will be numerous passengers with many different origins and destinations. One passenger may only be traveling from Washington, D.C., to Chicago; another could be connecting in Chicago to fly to St. Paul, Minnesota; and a third may have started his journey in Charlotte, North Carolina, and connected in Washington to travel to Chicago and onward to Shanghai, China. In this simple example, the one single flight from Washington to Chicago serves the demand for at least three different ODs:

Washington, D.C., to Chicago; Washington, D.C., to St. Paul; and Charlotte to Shanghai.

Measuring only the volume of passengers traveling from Washington, D.C., to Chicago would overstate the Washington-to-Chicago OD but would not reflect the demand on the other ODs flowing over the route. An OD model enables us to estimate the true travel volume by city pair based on the passengers' entire journey, and it allows airlines, airports, and tourism organizations to better understand, plan for, and serve their markets. Obviously, similar applications can be found in other modes, such as highway traffic studies and transit demand studies.

In most applications, the OD model is used with a combination of other methods, such as regression analysis, to help identify casual relationships between external variables and the OD distribution patterns. For example, William Crown at Brandeis University has conducted a study using an OD model to investigate the direction of the relationship between inter-regional migration and regional employment growth.

In his analysis, an OD model was applied to the inter-regional migration flows for the population under age 60 during 1975 to 1980 in the United States. The model found that people tend to move either to a nearby state in the same region or a popular destination area, such as the south Atlantic or Pacific region. The relationships between inter-regional migration and regional employment growth were examined in a simultaneous equations model using data from the OD model. The results show that manufacturing growth and migration are jointly determined, and that manufacturing growth has a stronger effect on migration than vice versa.

Another application of the OD model is to prepare OD distribution data for mode choice analysis. The information on trip distribution can be further used to understand the characteristics of travel demand. To achieve this objective, travel demand between each OD pair is estimated first in an OD model, which is then treated as a dependent variable. Explanatory variables usually include level-of-service variables (travel cost, on-vehicle travel time, and out-of-vehicle travel time) of specific modes and their competing modes, and social and demographic variables (such as population, personal income, and race) of both origin and destination, as well as the distance between an origin and a destination. Mode choice analysis allows decision

makers to determine which mode of transport will be used and which modal share results.

The OD model can also be applied to understand inter-regional flows of trade, migration, or transportation activities in a spatial context, if combined with spatial econometric techniques. Unlike traditional modeling analysis, which relies on the assumption of independence among OD flows, the integration of spatial econometric estimation with the OD model allows researchers to measure the spillover effects of inter-regional flows. This is because of the assumption of spatial dependence among the observations of OD flows. This is more realistic because the distribution of transportation OD flows is often influenced by geographic characteristics.

For example, in their Canadian journey-to-work flow study, Daniel A. Griffith and Kenneth G. Jones found that traffic flows from an origin are converged or diminished in accordance with the propensity of emissiveness of its neighboring origin locations, while the flows to the destination are influenced by the characteristics of its neighboring destination locations.

Under spatial econometric OD modeling, conventional gravity-like equations can be added to a spatial weighted matrix of OD flows or spatial weighted matrices of explanatory variables so that any spatial dependence can be controlled for. In general, spatial econometric OD modeling is valuable when the OD flow data has an issue of spatial dependence. The method provides a spatial perspective for examining OD flow patterns.

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See Also: Destination Choice Models; Transportation Modeling and Planning Software; Travel Demand Forecasting; Trip Distribution Models.

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Paratransit in Developing Countries

“Paratransit” is used as a general term for a “demand-response” travel mode, which is operated under more flexible operation and service arrangements than traditional fixed-route public transport systems. In developed countries, it typically represents a shared vehicle system for prearranged trips for riders who are eligible for the particular services (for example, people with special needs).

In developing countries, though, it mostly represents a local public transport system, which is characterized by flexible fares, unscheduled operations, and semifixed routes. Customers appreciate paratransit systems because of the degree of flexibility they provide, relatively lower operation and administration costs for the operators and government, relatively lower fares for the users, and higher labor intensity. On the other hand, because the system is mostly developed by the community or by private initiative, it is harder for it to be regulated by the government, leading to difficulties in not only standardizing the level of service but also other practical aspects, such as fares, safety, and the size and vehicle-type of fleets.

Paratransit is an alternative mode of public transportation that is provided by private or public operators for a certain group of users or to the general

public. This mode of public transport is adaptable in its routing and scheduling to individual users’ and/or operators’ desires in varying degrees. While the implementation and the use of this mode differs in developed and developing countries, it ultimately fills gaps not being served by private cars, buses, and other fixed-route systems.

Typically, vans or minibuses are used to provide paratransit service. In some countries, it is also common to use taxis, jitneys, modified station wagons, three-wheelers, and motorcycles.

In developed countries, paratransit is often used for demand-responsive systems, such as shared-ride taxis, dial-a-ride cars, and subscription or community buses. When it was introduced in the 1970s, paratransit was thought to be an ideal public transport service provision for users in areas of low-density land use and low demand (that is, areas not served cost-effectively by conventional public transport systems). Recently, it has been commonly used as a public transport system for people with special needs, such as travelers with various disabilities.

This service includes the U.S. Americans with Disabilities Act (ADA) paratransit system, a service required by the U.S. federal government after the 1990 passage of the act (only people who have been certified by the Regional Transportation Authority as a person with a disability are eligible to ride this service), and Call-n-Ride, a service that



A motorbike delivers milk and goods outside the city of New Delhi, India. Over half of all public transport needs are fulfilled by paratransit services in large cities in developing countries.

is similar to dial-a-ride, except that everyone is eligible and passengers can reserve a trip only one hour in advance.

In developing countries, paratransit is often used as the backbone of the public transport system. The lower standard of living, higher population density, and availability of a cheap labor force have together provided a bewildering array of transport modes bridging the gap between a fixed public transport system and private automobiles. More than half of the public transport demands in major cities in developing countries are served by paratransit, comprised of formally and informally operated minibuses, vans, taxis, station wagons, three-wheelers, motorcycles, and, in some cases, informally operated buses.

Rapid increases in urban population and per capita income, along with inadequate existing transport infrastructures and the lack of governments' fiscal and institutional capacities, have stimulated paratransit usage as an inexpensive and convenient public transport mode. However, some operators have neither official endorsement nor appropriate licenses, permits, or registration papers from public authorities to allow them to provide collective-ride services to the general public. Most drivers are low-skilled younger men who

migrate to cities from the countryside. The overabundance of idle labor in cities such as Jakarta, Indonesia; Nairobi, Kenya; and São Paulo, Brazil, makes informal transport an attractive employment opportunity.

Operation and Service Characteristics

The delivery of paratransit services may vary considerably as far as the degree of flexibility they provide their customers. Basic paratransit offers a service from a user-specified origin to a user-specified destination at a user-specified time. The basic service is modified to offer service only to provider-specified destinations or, in some cases, one destination, such as a site for social or medical service provision. In practice, the simplest service may consist of a taxi or small bus that runs along a more or less defined route with regular stops or allows passengers to alight on request.

At the other end of the spectrum—fully demand-responsive transport—paratransit systems offer the most flexible, on-demand, call-up door-to-door service from any origin to any destination in a given service area. In developing countries, paratransit modes range from simple nonmotorized human- (mainly hand-drawn or pedal-driven) or animal-powered vehicles to motorized minibuses. These paratransit modes are designed to provide flexible and frequent services to small communities and through narrow streets (where no other services operate) at a relatively low fare.

In terms of functional characteristics and service patterns, paratransit modes can be classified into three separate groups. The first is the “individual” type of paratransit, which provides a door-to-door service. For the second and third groups, the “shared” and “collective” types, the routes are generally fixed, but vehicles often and marginally deviate from the route based on passenger demand. The collective-type paratransit service sometimes cuts routes to pick up passengers going in the opposite direction.

Paratransit services can be operated by public transport agencies, community groups, or not-for-profit corporations, as well as by for-profit private companies or operators. Private individuals and cooperatives own the vehicles used for paratransit. Survey results in developing countries indicate that most drivers rent their vehicles from small-scale enterprises, with very few drivers owning their

vehicles. For example, only 9 percent of the jeepney (jeep-jitney) drivers in Manila; 18 percent and 13 percent of becak (bicycle-trishaw) drivers in Bandung and Jakarta, respectively; and 1 percent of samlor (pedicab) drivers in Bangkok are estimated to own their vehicles.

Mostly, the fares of individual-type paratransit modes are decided through negotiation between passengers and drivers. Some countries, such as India and Nepal, have metered auto rickshaws. But, in case of shared or collective types of paratransit, fixed fares are typically received from passengers, although, in some countries, the system can be more flexible, depending on the operator/driver.

Paratransit service providers who operate under a laissez-faire environment have to survive on low profit margins and to actively, and sometimes dangerously, compete for customers. This gets expressed as stopping almost anywhere to board passengers, driving overloaded vehicles, and using unsafe driving habits—what economists call “collectively damaging behavior” and is termed in Latin America, *la guerra del centavo* (the war for the cent). In this same vein, operators often “cream-skim,” offering frequent services at peak times and in peak directions, while leaving off-peak riders waiting until vehicles fill—sometimes for an hour or more.

To protect their interest, in many countries, these small transport providers join forces to form cooperatives. Cooperatives might be related to specific areas of the city or even a specific route, thereby called “route associations.” Cooperatives and route associations serve to organize the members in ways that increase the total ridership and profit of the routes, while also ensuring that all operators gain fairly equal shares of total revenues. In many countries, these cooperatives also act as organizational bodies that negotiate with the government over regulations and fares.

Advantages and Disadvantages

Each transport mode has its positive and negative consequences. Although the characteristics of paratransit modes differ based on their functions in different cities, commonalities include the fact that these modes are the usual means of movement among low-income individuals, cheap fares, low energy requirements, and higher labor intensity. Therefore, in some cities in developing countries,

the paratransit sector also generates a considerable number of employment opportunities.

For example, in India and Bangladesh, the share of employment generated by cycle rickshaw services is 12 percent and 12.9 percent, respectively. Further, most of these paratransit services are initiated and provided by the community. This is a significant help for the municipal governments in poorer cities, where budgets are stretched thin and technical capacities for planning, administration and regulation are insufficient.

Even in more modern settings, paratransit can be an important gap filler. Hong Kong's Public Light Bus entered the market to feed key train stations and housing and was later formally regulated by city officials. Mexico City's *peseros* (minibuses) were initially allowed because they could substitute for, without a need for subsidies, the failing public bus system.

The paratransit system has remarkably deep territorial coverage and integrates both planned and unplanned low-income neighborhoods into city economic and social systems. Recent studies also suggest that some types of paratransit services are instruments of social encounter and cohesion.

Taking advantage of compact vehicle size and unrestrained operation, paratransit can admirably respond to fluctuating markets, fill voids at relatively low fare in areas left by public transports, and substitute for much-needed public transport services without subsidies. They also respond quickly to changing markets, are more in tune with their passengers' demands, and have relatively low costs. By organizing into route associations and cooperatives, some operators can lower per seat costs to the point of being competitive with larger companies, research shows.

On the other hand, unlike a conventional bus service, the paratransit modes have no obligation to provide a service on those routes where demand is low. The operators provide services only where and when it is profitable for them. Often, to achieve more profitability, the shared and collective types of paratransit do not leave the terminal until the vehicles are full, leading to longer passenger waiting time and lower journey satisfaction.

Because the paratransit system mostly developed by community or market initiative, it is also harder to regulate by the government, leading to difficulties in not only standardizing the level of service

but also other practical aspects, such as fares, and the size and vehicle-type of fleets. In Mexico City in the early 1990s, for example, the rapid growth of the local paratransit services, which had gone from just 10 percent of the 30 million motorized trips daily in 1980 to 50 percent 10 years later, provided the minibus owners with unprecedented political power. This puts the regulators at a disadvantage in developing more structured and planned public transport services.

On-the-ground relationships between paratransit and the existing planned services are also far from stable, with that relationship vulnerable to descending into destructive competition for passengers. Within the general public transport system, the planned public transport services usually occupy higher-demand corridors and provide a relatively higher quality of service, while paratransit services are frequently (but not always) located on less desirable corridors and/or areas with physical accessibility constraints. This creates tension between the two systems and any improvements/upgrades of planned services tend to create social unrest among paratransit users.

Other negative effects include paratransit's contribution to the overall reduction in traffic speed and the decrease in road capacity, which can cause appreciable congestion. In many developing countries, paratransit's indiscriminate stopping and starting may hamper the normal flow of traffic. For example, in Jakarta, in terms of road space utilization per passenger, it is estimated that paratransit was 10 to 13 times more inefficient than a conventional bus.

There is also some indication that the use of paratransit significantly contributes to the road traffic accident rate. This remains a hard-to-regulate practice, and operators sometimes have the opportunity to drive up fares until it becomes an almost inaccessible mode of transport for the urban poor, as was the case with the *matatu* in Nairobi.

Conclusion

While modern mass rapid transport systems, such as the tram and urban rail, may relieve transport and traffic congestion problems, these systems require a huge capital investment and take a very long time to build—something that is almost impossible for most developing countries or low-density areas in developed countries to have. In

such circumstances, paratransit modes will still be able to serve the community in a much cheaper, quicker, and more responsive way than the fixed public transport system.

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See Also: Demand-Responsive Transit, Evaluation Studies of; Dial-a-Ride; Jitneys; Shared Taxis.

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Park-and-Ride/ Kiss-and-Ride Lots

Park-and-ride lots are provided for the purpose of facilitating patronage of fixed-line transit by aggregating ridership from a low-occupancy feeder mode (that is, private vehicles). Park-and-ride has been very successful in increasing the patronage of public transport systems within sprawled North American and Australian cities and the transit mode share of residents in suburban and ex-urban locations generally.

Park-and-ride lots are most typically associated with metro or heavy rail rather than bus rapid transit (BRT) or light rail transit (LRT). This is because the catchment of metro and heavy rail stations is larger, these systems have higher capital and operating costs, and they are designed to facilitate longer (regional or subregional) trips than BRT or LRT.

Park-and-Ride Yield and Function

The yield of park-and-ride bays and their design and their orientation to the transit station often depend on two key factors:

1. The broader form and function of the station. This includes whether it serves as an interchange between feeder bus services and fixed-line transit, or is embedded within a transit-oriented development (TOD) precinct, which generates a significant proportion of walk- and cycle-on patronage.
2. The distance of the station from the central business district (CBD).

There is a clear relationship between the two variables, with stations farther from the CBD often having relatively fewer TOD characteristics. There is also less opportunity for sufficient patronage to be generated locally to warrant investment in and operation of an outlying station along a transit alignment without provision of park-and-ride.

Park-and-ride lots are particularly popular in contexts where there is a requirement for patronage targets to be hit early following the opening of new transit stations and a low perceived (and sometimes actual) market appetite for TOD, which could be an alternative source of patronage. Logically, this most

often applies in suburban and greenfields train station locations.

Park-and-Ride User Groups

The typical park-and-ride user is a commuter. This reflects the radial characteristics of many fixed-route transit systems. While there may be some churn of bays over the course of a weekday, overall occupancy may remain quite static. Moreover, depending on the supply of park-and-ride relative to demand, commuters may need to arrive in advance of their preferred travel time on transit to secure a bay. Over time, park-and-ride may fill earlier and earlier because of this adjustment to travel times.

For these reasons, park-and-ride tends to contribute to peak-travel-demand management issues, meaning it encourages and concentrates transit trips inbound to the CBD during the morning peak and outbound in the evening peak. Peak travel demand is a growing issue in many cities, because it requires high capital and operational expenditure to supply the capacity necessary to meet short-run tidal flows on the transit system.

The use of park-and-ride by noncommuters will be higher in cities where there are more circumferential transit lines and decentralization of jobs. However, these cities are also likely to have fewer park-and-ride provisions overall, because of the greater potential for rail patronage to be generated by feeder modes other than private vehicles. Such cities, including many in western Europe, Singapore, and Hong Kong, are also less likely to experience one-way peak travel demand problems.

Park-and-Ride Location

From a planning perspective, it is desirable to locate park-and-ride within a reasonable walking distance of the station, but without compromising station access for other modes of feeder transport. A walking threshold of around 450 yards (411 meters), or about a five-minute walk, is often accepted; however, this has to be considered in the context of peoples' overall journeys. For example, there may be a number of legs to a commuters' typical journey to work (for example, drive-transit-transit-walk), and the imposition of a five-minute walk from their parking space to a rail service could be sufficient to encourage them to drive to work instead. This also depends on the availability and cost of parking at the end destination and levels of congestion on the road network.



A sign marks the park-and-ride lot at the Chicago Transit Authority's Garfield station in Chicago, Illinois. Planners aim to have park-and-ride facilities within a five-minute walk (or about 450 yards or 411 meters) of transit stations.

Determining the location for park-and-ride involves a series of trade-offs, depending on the extent to which a planning authority wishes to favor different feeder modes. Even so, it is critical for the authority to remember that even park-and-ride users become pedestrians when they exit their vehicles and walk to the transit station platform. This necessitates provision of appropriate pedestrian infrastructure within the park-and-ride lot.

Vehicle access to park-and-ride lots is also an important consideration, and this depends on the geography of the local road system. Furthermore, land tenure and use may limit where the park-and-ride can be constructed. In some instances, a series of smaller park-and-ride lots are provided in lieu of a larger facility to try to address this range of station-specific issues. However, this is less spatially

efficient because access points, aisles, and internal pedestrian infrastructure are still required within each facility.

Kiss-and-Ride

Kiss-and-ride is distinct from park-and-ride because the bays provided must be within closer proximity to the stations to permit drive-up drop-off and pickup of passengers.

Kiss-and-ride bays experience high turnover—notably in peak hours—because they are specifically designed to discourage longer-term parking. Thus, they are a more spatially efficient mechanism to increase transit patronage; however, they require a trip by someone other than the transit patron who is able to make the trips to and back from the station. For this reason, kiss-and-ride bays are usually provided in conjunction with park-and-ride facilities. Because the idea of kiss-and-ride is quick depositing and retrieving of passengers from cars—which results in the high churn of traffic and spatial efficiency—kiss-and-ride is generally placed in greater proximity to the station than park-and-ride.

Parking Management

Given the well-established relationship between park-and-ride and kiss-and-ride and their ability to increase patronage of public transport, transit authorities may be loath to charge users of the facilities. While price elasticities may be relatively low, the introduction of or increase in costs of parking may induce some users to switch completely to car-driver trips.

Parking is not free to provide, though, and there is increasing understanding from the public that at least some of the cost of supply and operation is necessary to be recouped to ensure the longevity of the service. In Perth, Australia, in some station precincts, the park-and-ride fee is priced to be roughly equivalent to a typical feeder bus fare, which also helps avoid any alienation of either feeder bus or park-and-ride users. Often the parking lot for which a charge is levied provides additional amenities, such as security fencing, closed-circuit TV, and lighting.

Control of access to park-and-ride poses further challenges. While the intent of supplying park-and-ride is to benefit transit users, park-and-ride facilities can be attractive to non-transit users, too, particularly if public parking supply in the vicinity is

limited or costs more. For example, public parking that serves retail or commercial land uses may cost several times more to use than an adjacent park-and-ride lot. The opposite is also true in the case where parking associated with retail or commercial land use is provided free to customers. This may tempt some park-and-ride patrons who are required to pay for parking to take advantage of the free parking.

One method to control the use of park-and-ride is to link payment to the use of transit. This requires some sort of smart system whereby the transit authority can validate use of park-and-ride by confirming that the user is a bona fide transit patron. The introduction of smartcards in some cities, such as the San Francisco, California, metropolitan area's Clipper Card, enables the integration of park-and-ride and transit-fare payment by providing an electronic mechanism for this service to be performed.

Long-Term Opportunities and Constraints

Park-and-ride lots may sometimes be intended to function as land banks. Because they are often situated on public land and maintained and operated by a government agency, planners might have a longer-term plan to replace at-grade lots with decked structures when the market is able to supply sufficient local activity intensity to generate patronage through other feeder modes. However, there are often difficulties making such changes to park-and-ride once it is constructed, because of the following:

- Existing at-grade park-and-ride can create poor amenity within close proximity to stations, which can be a disincentive for investment in TOD opportunities by developers who are leading the market.
- The cost of supplying park-and-ride in decked structures is significantly higher than at-grade facilities, which often becomes a cost imposed on the private-sector developers the government requires to fund the conversion.
- Even reduced park-and-ride supply can generate significant general-vehicle trips within close proximity to stations during peak periods, which can affect feeder bus operations and pedestrian and cyclist amenities.
- Park-and-ride tends to generate a large station catchment; patrons who become

accustomed to using the park-and-ride will tend to oppose any reduction in the supply of facilities they rely on to fulfill their travel needs. This may be their only means of gaining access to rail transit.

Selling of air rights over park-and-ride lots is gaining popularity in North American and Australian cities as a means to help fund the conversion of at-grade park-and-ride lots to decked structures. The right to development is usually highly valued, given the land premium that tends to be associated with proximity to stations.

This system has an established track record in Singapore and Hong Kong; however, there are extreme activity intensities around many stations in these cities and the development market is very savvy to the locational advantages of transit proximity. Furthermore, the Metropolitan Transit Railway Authority in Hong Kong, which operates the metro system, has significant development powers as far as permitting the leverage of value from transit orientation.

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See Also: Bus Rapid Transit; Light Rail Transit; Mixed-Mode Transit Systems; Mode Share/Mode Choice; Parking Demand; Parking Lots; Parking Planning and Management; Parking Regulation and Enforcement; Transit-Oriented Development; Travel Demand.

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Parking Cash-Out Systems

By 2035, there will be a projected 1.7 billion vehicles on roads worldwide. As of 2007, there were already 254.4 million passenger vehicles registered in the United States alone, according to the U.S. Department of Transportation (DOT). The result of this burgeoning international fleet of vehicles can be seen in increased traffic congestion, accidents, and damage to roads.

Another result is a massive volume of vehicular emissions, which come in the form of exhaust system by-products, including carbon dioxide, carbon monoxide, nitrogen dioxide, and sulfur dioxide. These emissions are a leading cause of many common air pollution problems nationwide. Correspondingly, cities with significant amounts of traffic also typically have air quality problems such as smog.

State governments and businesses have expressed an interest in reducing those problems by attempting to reduce the number of cars used in home-to-work commutes. Their primary approach to this effort has taken two forms. One is to increase the funding and quality of mass transit in their area. The other is to provide consumer financial incentives, such as parking cash-out systems.

Basics

Many employees of businesses are offered free or subsidized parking by their employers. Particularly in crowded cities where public parking spots are quickly taken, this can be a notable benefit to employees who drive. At the same time, it tends to

have the unintended effect of encouraging employees to drive their own cars to work. After all, they are assured a good parking space each day and know that they will not be inconvenienced having to hunt for one. The net result is a higher number of cars being used, with the correlated emissions and pollution problems.

Legislators decided that a way to decrease the number of cars on their state's roads was to reduce employee car use through parking cash-out systems. These mandate that employers offer cash incentives for employees who give up their parking places. The hope is that employees who voluntarily accept these incentives will stop driving by themselves to work. Instead, they will take mass transit, such as a bus or a train, or carpool with someone. In cases where the cash-out system is adopted, there will be fewer cars on the road, achieving the program's objective.

Typically, employees who give up their parking spaces get the money for doing so on a monthly basis. This is most convenient for employers, because they can reassign those spaces to others or simply stop paying to rent them. However, there are some cases where the payments are daily, correlating to the number of days the particular employee did not drive to work. Although substantially less attractive to employers, this approach does still reduce the number of cars on the road.

Challenges of the Program

Historically, a key challenge to fully implementing this type of program has been a lack of enforcement. In states where it has been implemented, some employers fail to comply. With insufficient government oversight in place, the noncompliance of employers is rarely addressed by authorities unless there is a specific employee complaint.

Such complaints are rare for two reasons. One is that many employees want to drive their own cars, finding it to be the most convenient method of commuting. Because of that, they have no interest in giving up their parking space, regardless of any financial incentive to do so. The other reason is that commuting employees simply do not know about the program and, therefore, have not considered it as an option.

Employers, in turn, may make only minimal attempts to inform staff members about it. They may not embrace the environmental goals, or may

feel that subsidizing parking is a critical way to attract and retain quality employees. California has attempted to address this by making cash-out payments from employers deductible as business expenses. As would be expected, this improved tax treatment has increased business interest in the program, providing a blueprint for other states that try it.

California faces a separate challenge with the law, which is the fact it only applies to some businesses. Specifically, it applies to businesses that can immediately reduce their operating expenses by discontinuing the rent or lease of surrendered parking spaces. Those that can are able to quickly recoup cash-out payment costs, but not those that own their spaces or cannot stop renting spots on an individual basis.

Rhode Island

Parking cash-out systems are handled differently in Rhode Island. While California pioneered the program decades ago, the Rhode Island government has taken a unique approach to it. Under the state law 37-5-7.1, businesses that currently provide employee parking spaces are required to offer Rhode Island Public Transit Authority (RIPTA) passes as an alternative. A RIPTA pass allows commuters to take unlimited bus rides throughout the state. A replacement pass is typically issued at the beginning of each month, and each bus includes conveniences like bicycle racks. With frequent trips to most destinations, this can be an attractive option for many commuters.

Employers are told that active involvement in the program will help their public images because helping the environment is viewed favorably by many consumers. Employers are also told that they will save money, because the cost of a transit pass is less than the cost of a leased parking space. In cases where employers own the spaces, they may be able to convert those to use by customers, potentially increasing business and revenue.

Voluntary participation by employees is encouraged in a similar way by mentioning benefits, including saving money that would be spent on gas, helping protect air quality by having their car on the road less, and minimizing the stress associated with driving. Those who are motivated by such considerations may also choose to carpool, achieving the same effects. The government of Rhode Island

is aware of this and has set up park-and-ride lots offering free parking to carpoolers.

Additional Considerations

Although some employers have viewed subsidized parking spaces as a critical recruitment tool, their prospects in that respect can actually improve with a parking cash-out system. After all, not all employees want to drive their own cars to work. Some might enjoy carpooling for social reasons, or have a personal preference for riding mass transit. In these cases, they will want their chosen method of travel to be recognized and subsidized by their employer, just as driving is now. An astute employer can recognize this and communicate a desire to benefit all employees, regardless of their mode of transportation. By combining messages to employers and employees with greater publicity, parking cash-out systems are likely to become more popular in the future. Millions of commuters care about their impact on the environment and view mass transit or carpooling as a good way to help.

In addition, publicity about the availability of buses and trains helps the programs to do better. If commuters can feel more confident that a bus will get them to work on time, they will be more likely to take it. Businesses can also promote carpooling by designating special parking spaces for it and offering encouragement in meetings and materials. Ultimately, though, it will always come down to commuter choice. If commuters can be convinced that it is a good idea, they will want to be a part of it.

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See Also: Economics of On-Street Parking; Parking Finance; Parking Planning and Management.

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Parking Demand

Parking is an essential, though often overlooked, component of all transportation systems. Transportation systems may be conceived of as having two distinct physical components: a network of guideways, with vehicles that travel over that network, carrying passengers and/or goods. In this view, parking facilities represent specialized nodes along the network for storage and servicing of vehicles not in active use.

While the term *parking* usually refers to storage for automobiles and trucks, in infrastructure terms, vehicle storage also looms large in the maritime and air transport systems. The physical networks used by air and water transport are mainly supplied by nature, but the majority of investment apart from vehicles is in terminals (seaports and airports); berthing of ships and aircraft is an important component of such terminals.

Parking demand studies focus on cars and trucks for good reason. While the global maritime and aviation fleets are numbered in tens of thousands, cars and trucks number in the millions in most nations, and, in the United States, the motor vehicle fleet is nearly as great as the population. Moreover, compared to other modes, the average car is infrequently in active use.

In the United States, travel surveys reveal the typical private vehicle is in motion less than one hour a day. This means that more than 95 percent of the time, the vehicle must be parked. A typical automobile parking space requires approximately 320 square feet (30 square meters), including necessary maneuvering space, so the demand for parking space is prodigious in countries and regions where motor vehicle ownership and use is common.

The demand for automobile parking is a by-product of the demand for automobile travel. A motorist travels to a certain destination for a certain purpose (for example, to work or to shop) and must store the vehicle upon arrival. From the motorist's perspective, a parking space directly adjacent to the destination is ideal, and the desirability of a parking space decreases with the amount of distance, cost, and difficulty of reaching the nearest parking space to the desired destination.

Parking Demand Studies

Typically, parking demand has been studied in association with particular land uses (for example,

residential, industrial, and retail). After determining the nature, intensity, or size of the land use at a site, the number of vehicles parked at the site is surveyed. The objective of the survey is simply to count the number of vehicles parked at the time of peak parking demand; in practice, parked vehicles are often counted throughout the business day in order to determine when the peak period occurs. A side benefit of day-long parking surveys is that they give an indication of parking demand fluctuations throughout the day, which is important for determining the potential for shared parking, discussed further below.

A standard reference for determining parking demand is "Parking Generation," an informational report by the Institute of Transportation that provides parking demand ratios for more than 100 land uses and building types. "Parking Generation" is updated from time to time; the current edition, the fourth, was published in 2010. Most of the data in it are derived from surveys of single-use suburban developments with little or no significant transit ridership or ridesharing, and the parking facilities at these sites are typically reserved for the exclusive use of the traffic generated by the site, at no charge. At such single-use sites, the demand for parking will be high, given the convenience of the parking and the lack of alternative access modes.

As a result, analysts cannot directly apply such parking demand ratios in downtowns and other locations where there are close-knit, mixed land uses. Such rates will overstate parking demand significantly by overlooking the ameliorating effects of the motorist making several trips to different land uses from a single parking space, as well as the effects of transit usage, ridesharing, or other forms of traffic demand management possible in dense, mixed-use areas.

The process of developing parking demand for downtown sites and other complexes, and the process for isolating the demand for specific land uses in such environments, has yet to be standardized. In general, it requires surveying both parking space occupancy and turnover, and interviewing visitors about the number of trips made to individual establishments within the study area.

Shared Parking

Shared parking occurs where parking spaces are available for use by more than one land use or

establishment. Given the space intensity of parking and high value associated with developed land, from an economic standpoint, it is sensible for proximate land uses to share parking. In order for parking to be shared between two or more uses, one or both of the following must occur: (1) the parking demand of these uses must peak at different times; and (2) the land uses must be complementary, that is, some visitors to one land use are likely to visit the other via walking from the first use.

For example, parking demand for a cinema will typically peak in the evening, and so the cinema may be able to share parking with an office building, which peaks midday. A laundry in a mixed-use district may not need dedicated parking if most of its patrons are employees of nearby establishments.

Parking Demand and Parking Pricing

One of the challenges of setting parking requirements and designing access and parking systems is that parking generation and demand are not fixed; both depend on the price of parking. Many smaller cities and suburbs are planned on the tacit assumption that parking should be free to the user. However, parking is never free to the supplier. Typically, the land and construction costs amount to thousands of dollars for surface parking and tens of thousands of dollars for structured parking.

Charging for parking or increasing parking price reduces demand by shifting driver trips to other modes. Some demand may shift to other business districts and establishments that do not charge for parking, which causes resistance to implementing parking charges. It is important to realize that not charging users for parking does not eliminate parking costs, only that the costs of parking are socialized.

Cruising for parking represents another socialized cost of underpriced parking in congested downtown areas. Cruising for parking, defined as circulating near one's destination at low speed, looking for a parking space on the street, is motivated by a combination of preference for on-street parking (particularly if it is free or underpriced), and uncertainty about the existence and location of such a space. In larger downtowns at peak times, a large fraction of vehicular traffic and congestion is attributable to cruising for parking.

In conclusion, the need to park a vehicle requiring a large amount of space affects many aspects

of urban travel—the travel mode used, the destination chosen, the time of the trip, and how and if other trips are linked to the primary trip. Cruising for parking adds pressure to already congested networks as motorists seek difficult-to-find or cheaper parking spaces.

Given the complexity of motorist parking behavior, no unified method has been developed to fully model parking activities. To date, parking demand studies have often overlooked the effects of parking or the lack of pricing. In the future, pricing and traveler information systems promise to better integrate parking demand and choice with the demand for the trip itself.

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See Also: Economics of On-Street Parking; Parking Generation Rates; Parking Planning and Management; Parking Regulation and Enforcement.

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Parking Design Requirements

There are more than 2 billion parking spaces in the United States, more than 85 percent in and around metropolitan areas with more than 25,000 in population. Parking design refers to the decisions—architectural, engineering, environmental, economic, and even cultural and social—that must go into constructing new parking spaces or converting

used or empty spaces into new parking spaces or devising regulations guiding the designation of particular streets or specific parts of streets for parking, decisions that must take into account a variety of factors including land usage, demographics, traffic volume, and pedestrian and traffic flow.

While municipal decisions concerning designing on-street parking impacts residents, visitors, and business owners, design requirements primarily involve the development and construction of parking lots. In major metropolitan downtown areas where more than a third of the available land may be given over to off-street parking lots (indeed, parking lots could be their own nation; across the country, parking lots consume more than 3,500 square miles, nearly twice the size of Luxemburg), urban planners consider parking design one of the most pressing (and neglected) issues facing contemporary cities.

Since the explosion in vehicle ownership after World War II, critics of the urban landscape have decried the intrusion of parking lots as a blight, a dead-end strategy in which cities cannibalize themselves, providing more convenient parking spaces to encourage people to come downtown, to make the lives of residents more convenient, or just to improve transportation to and from work or entertainment and sports events. But in the relentless determination to make mass parking available, cities have paved themselves over, surrendering to the asphalt look that creates an aesthetically challenged urban landscape, thus ironically driving away the very people—entrepreneurs, tourists, potential residents—they had sought to attract in the first place. That effect—the so-called Pensacola parking syndrome, named after the Florida panhandle city where the effect was first documented—measures the difficult challenges facing parking designers in the postmodern city.

Of course, city residents prefer private or on-street parking. Since the early 1960s, cities routinely required a specific ratio of cars to available parking spaces in and around housing units and retail sites. While mandating a steadily escalating number of spaces (or stalls) has done little to improve the visual aesthetics of a city, the limited availability of accessible parking spaces has created enormous friction among residents who must vie for accessible parking—ironically, urban planners have long argued that there is abundant space for parking in cities, save that drivers demand the closest possible

spaces, despite the obvious: parking farther away and walking actually saves time (and frustration) over driving around looking for more convenient parking. However, limited parking availability in cities has created a market for parking spaces—they are secured as part of housing agreements and can be owned and passed down through a family in a legal chain. Indeed, tandem parking spots, that is two parking stalls one in front of the other, most often in pull-offs from the street, are valuable commodities routinely bought and/or auctioned off, as they provide guaranteed parking for two cars.

Because local governments are now attuned to often vocal green objections to over-paving, designs for proposed lots routinely begin with gathering data about need, specifically the volume of vehicular traffic about a particular traffic generator, say a business or a mall or a sports arena, or a general assessment of a block or two of businesses, shops, and restaurants within walking distance of the proposed lot. Data is gathered on existing parking facilities, their location, the number of parking stalls, and the rates charged plus the time parameters to park there, as well as parking stall turnover. Based on this data, engineers project a specific number of parking spaces a new lot would need to accommodate using an elaborate mathematical formula to derive the probability of what is called “rejection,” those occasions when vehicles cannot find a parking stall. When the rejection number is high, engineers recommend constructing the new parking lot.

Parking design requirements work to maximize the number of available stalls without compromising the basic maneuvers drivers who are parking cars require. Indeed, parking design mandates designing lots that allow drivers to pull into the stall in one easy maneuver. The basic process for parking—entering the lot off the street, working the aisles looking for an available stall, entering the stall, exiting the vehicle, walking to the destination, returning and exiting from the parking stall, maneuvering to the exit, and returning to the street—guides the design requirements. In general, average-sized cars are allotted about 300 square feet of parking space in the traditional 90-degree stall, that is simply pulling straight in. That span is adjusted when accommodating special-assistance vans, in which case federal guidelines mandate a wider space for stalls. When parking lot design



A parking lot for a shopping mall in Gjøvik, Norway features traditional 90-degree spaces, wide search aisles, and extensive crosswalks. In parking design, average-sized cars are allotted about 300 square feet of parking space in the traditional 90-degree stall (pulling straight in). Special-assistance vans are provided a wider space, per federal accessibility guidelines.

puts cars at angles, most often 45 or 60 degrees, maneuvering in the lot aisles must accommodate that loss of space, most often by making aisle traffic one way.

Parking design also requires strategic planning of the lot itself. The entranceway to the parking lot, often positioned, much as the egress gates, in mid-block to avoid conflict with intersections, is usually designed to the specifications of a traditional double-width garage. The entrance and exit must provide the accessibility and user-friendly environment that public service spaces like parking lots need to provide; they are designed to minimize traffic holdovers extending into the flow of traffic on the adjoining streets. Similarly, because many lots require payment and hence must provide exit gates with stations, a rule of thumb for parking design is two exits for every one entrance.

The actual parking lot design must in turn take into account the dimensions of the individual

parking stalls, specifically, the needed width of the search aisles (based on a mathematical computation of the size of potential vehicles ranging from sports cars to minivans and sport-utility vehicles, the average stall size is 6 feet by 18 feet); the angle of parking desired (straight in or at angles, the most familiar being the interlocking herringbone pattern, stalls each at 45 degree angles in which the bumper of one car abuts the fender of another, but other parking designs put cars at angles of 60 degrees allowing for considerably tighter spaces and, hence, additional vehicle volume); and the total radius sweep necessary to allow vehicles to execute search maneuvers such as turning (aisle width is most often 18 feet).

The reality is that the increasingly limited available parking space in urban environments demands mathematical precision in designing lots and in weighing decisions about designating street parking. There is an evident imbalance—at once

too many spaces and too few spaces. Given that now in America there are three parking spaces for every one car, parking design protocol is ripe for radical reform.

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See Also: Parking Finance; Parking Lots; Parking Planning and Management; Traffic Flow.

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Parking Finance

Managing financial policies and strategies to provide for and support parking capacity in a range of urban and nonurban environments is a very large and pervasive challenge for city planners, one that involves transportation authorities at the state level as well as federal administrators from a range of agencies. While many localities are burdened by somewhat antiquated parking requirement statutes that effectively hamper both public and private real estate development and deter quality-of-life improvements, more and more planners are discovering new ways to define parking-space requirements. At the same time, they are employing new types of financial instruments, alternate revenue structures and sources, flexible budgetary considerations, and diverse funding channels to support their 21st-century parking infrastructure and operations.

Automobiles are, on average, inactive at least 95 percent of the time. In other words, cars are seldom not parked. It is not surprising, then, that parking is an approximately \$30-billion industry in the United States, according to the International Parking Institute (IPI).

Although there are signs of transition away from a dominant car culture on many fronts, such as some movement to other modes, the fact remains that if planners do not work the parking of cars and access by automobiles into their intermodal schemes, the odds for overall success are reduced. In many cases, parking makes other modes work, because most nonautomotive travel and transportation modes generate the need for automobile parking.

One example is the case of the Bus Rapid Transit (BRT) system in Pittsburgh, Pennsylvania, which inaugurated its first busway in 1977 and has been expanding periodically ever since. The most recent five-mile West Busway sector opened in 2000. Its use at first lagged that of the other routes, but city planners predicted the additional availability of 2,000 parking spaces would galvanize ridership almost instantly. Their confidence was based strictly on real-world experience; they had built thousands of parking spaces in park-and-ride centers sited near the other busways. Similar experiences are recounted in places as diverse as Ottawa, Ontario, and Milwaukee, Wisconsin—where more than 30,000 parking spaces were deemed vital to the launch and success of its Transitway Plan of 1990.

Development and Flexibility

The space necessary to meet municipally required parking accommodation for real estate development in many jurisdictions can average roughly half of the available project space. This dominant feature means that decision making on the parking issue can substantially determine the size and scope of financing needed to enable a given development to proceed or to stall out.

In real estate development, a general rule is that the lower the number of required parking spaces, and the lower the cost of those spaces, the lower the project development costs will be as a whole. Land costs and complex site configurations are additional factors. These are all rather direct matters to comprehend and to incorporate into development planning.

The financial return side of the development equation, however, tends to be less predictable than the cost side. The core factors include the amount of marketable space, occupancy rate, and rental or selling price of the space. Plotted against these variables is the balancing of parking as an amenity against parking as a consumer of space that could be otherwise be developed to expand the liveable

or ancillary attraction space of a project—in other words, space that may or may not be worth more in a nonparking use.

Lenders who are sensitive to local heritage, legacy, and lifestyle issues are typically more likely to expend political capital in working with municipal authorities to find alternatives to the strict application of existing parking statutes. City leaders, for their part, might also be willing to see the bigger picture, as was the case in the development of Circle Centre in downtown Indianapolis, Indiana, in 1995. To solve the parking challenge of this \$300-million mixed-use development, the city, the developer, and other local constituents were able to fashion a shared-parking plan. In this case, rather than constructing the 6,000 new parking spaces that would technically have been required, the developer was permitted to build just 2,815 spaces.

Two shared-parking factors went into this decision. The mixed-used nature of the project meant that a single parking space could be utilized by customers for multiple destinations within the project, with different flows at different times of day. Further, there were 12,000 existing off-site parking spaces in the vicinity available for Circle Centre employees and visitors to use, especially during off-peak times. These two factors altered the fundamental math of the situation, revealing that less than half the required-by-statute 6,000 on-site parking spaces would be necessary. The net result was a development cost reduction of some \$30 million, as well as a cut of about \$1 million in annual operating costs. The financing of the project was more readily attained under these circumstances.

Municipal Options

Often, a municipal planning body perceives its choices on parking development as confined to simple decisions, such as whether to invest in surface, structured (above-ground garage), or underground facilities. Knowing the cost of an underground facility can range to approximately twice the amount per space of an above-ground or structured garage—and that surface lots cost only a fraction of that—tends to form the core “given” in such decision-making processes.

Another core tenet is that, rather than determine to build and operate a garage itself, a city or similar body can elect to lease from a developer, potentially freeing itself from much of the

financing decision making and responsibility it would otherwise be liable for. Still, a private developer may very well insist that the city share the financing burden through a bond issue. A developer may also negotiate tax deferral or tax reduction for a number of years as compensation for taking on the responsibilities of construction. The city, therefore, must prudently consider how the revenue streams from parking fees will be divided between itself and such a developer.

In any event, several types—at least three main categories—of beneficial constituents must be considered beyond the developer. These constituents include the parking facility users; the merchants, other property owners, and businesses within walking distance of the facility; and the general municipal area itself. All stand to benefit. To the extent that this can be predicted and demonstrated in clear fashion, substantial revenue from each category of parties can be reasonably expected, without too much in the way of political objection.

One typical contributing funding mechanism based on this principle is a business-improvement district or local property-improvement-area designation, which would allocate various portions of cost to those locally benefiting. Such funds are used to retire bonds and, after that event, to defray operating expenses.

Public–private partnerships of this type are often established to inaugurate and operate municipal parking structures and systems. They generally prove integral to success.

For example, in Kirkland, Washington, the city Parking Advisory Board recommended a financial plan that would (1) commit to price on-street parking to gain reliable levels of local user payments by way of a pledge for retirement of parking revenue bonds for a portion of the city’s share; (2) set up a local improvement district containing properties within walking distance of the new public parking supply, to be actuated when bonds are sold in order to finance a portion of the cost; and (3) include new parking supply in the City of Kirkland Capital Improvements Program, “to be financed from general revenue and/or traffic impact fee bonding.”

A plan was devised consisting of parking revenue + business dues + taxes and fees = bond payments for the capital investment needed to satisfy the city’s parking finance needs. This benefited all

parties, and the plan of spreading the risk was a factor in gaining more favorable borrowing terms.

Hidden Revenue

There are hidden financial streams in some already installed parking systems. The city of Tampa, Florida, for example, discovered that replacing outdated lighting in its parking facilities cut its expenditures for electricity in half. This yielded a direct and recurring financial benefit to the city. In Los Angeles, city leaders were able to partner with private development interests in order to execute a planned upgrade of parking meters at no cost to the city—and generated revenues that funded additional new equipment.

In San Francisco, without adding a single new parking space, the city uncovered new revenue by maximizing the use of its existing parking capacity. The SFpark pilot program deployed federal congestion-mitigation funding to test a demand-adjustable rate system for on-street parking in several districts of San Francisco. The success of the program led to a similar federally funded project in Los Angeles, dubbed LA Express Park.

Projects in these cities and elsewhere are increasingly tapping the potential of wireless technology to aid drivers in identifying parking space availability, as well as to pay for parking by mobile device. This simple solution holds major promise as a dramatic means of cutting cost while increasing parking utilization to capacity, thereby unleashing otherwise forgone revenues—and, in essence, providing an alternative to the need to seek and be bound by additional financing and debt.

The federal government can be a vital source of direct funding for some types of parking solutions. For example, within the framework of the Moving Ahead for Progress in the 21st Century Act (MAP-21), enacted in 2012, the Surface Transportation Program provides an annual average of \$10 billion in flexible funding that may be used by states and localities for projects “to preserve or improve conditions” in a wide range of public transportation facilities. Among these facilities, a variety of parking and parking-related infrastructure types are specifically enumerated. These include truck parking facilities, electric vehicle charging infrastructure added to existing or included in new fringe and corridor parking, electronic toll collection and wireless electronic-funds-transfer-enabled

smart-meter systems, and parking areas connected with mass transit stations and terminals.

Self-Funding Ideal

Institutions other than municipalities have learned to utilize parking as operations that can be—at least in part—self-funded. The University of Tennessee (UT) in Chattanooga, for instance, generates parking-related revenue from decal sales, tickets and fines, visitor passes, event revenue, its main parking garage, and a sales tax. The system typically generates a modest surplus of revenue on an operating basis, but it has lost money when capital investment or major new expenses are factored in. The wild card is that UT students control the parking financing, and this means each new wave of students must be made aware of the underlying costs and financial strictures of the system that provides parking convenience to them.

Environmental concerns can contribute to financing options in support of parking capacity, in a sense providing an additional measure of self-funding. Employers in California have availed themselves of one such option, the Parking Cash-Out program. This is a scheme conceived to mitigate some of the very real and, in California, exhaustively quantified costs of reliance on the automobile for commuting, and the resultant highway congestion (for example, environmental and health cost, lost productivity, road wear, enforcement and first-responder personnel and systems cost). Under Cash-Out, employees who opt not to use private on-site parking at company work locations receive a cash payment. This incentive has the net effect of actually relieving pressure in other parking areas, because the cars these employees would have driven now stay home in their private spaces.

Limits and Capacity

Some planners and policy makers look at city centers and perceive an oversupply of existing parking and parking-adaptable brownfields (underutilized or outdated structures and neighborhoods). This perception can have various financial implications when they are considering the development of new mass-transit systems, and, in particular, the transit-oriented development (TOD) that accompanies any planning for the construction and activation of local stations to support intercity rail, subways, monorails, bus rapid transit, etc.

TOD goes hand in glove with city center marketing and urban core redevelopment, a powerful trend over the last several decades. The competitive environment both within and between city neighborhoods means that parking has become a more significant bargaining chip in these cases. Light rail and commuter rail stations, as examples, are often designated as either feeder stations or destination stations, which results in different manifestations of TOD projects.

Feeder station areas are typically residential or suburban areas that often have TOD projects, including neighborhood restaurants, cleaners, and grocery stores. As such, these stations are usually less dense and have park-and-ride lots.

Destination stations, most often sited within the central business district or near major entertainment venues or government centers, tend to foster high-density TOD that can include mixed-use housing, office complexes, stadiums, arenas, and other entertainment facilities. TOD around these destination stations usually does not have park-and-ride lots, and they are typically located in areas with few parking spaces. In an effort to reduce automobile congestion and create more space for TOD commercial and residential development projects, many cities have modified zoning codes to effectively lower the required number of parking spaces in areas adjacent to these stations. This, however, raises the value of any nearby parking facilities, tips the pricing dynamic in sometimes unpredictable ways, and alters the calculations for the financing of parking in the TOD area.

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See Also: Airport Parking and Ground Transportation; Parking Cash-Out Systems; Parking Demand; Parking Generation Rates; Parking Planning and Management; Parking Revenue and Collection; Parking Structures; Tourism; Transit-Oriented Development.

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Parking Generation Rates

It is anticipated that most land uses will generate or attract private vehicle trips. Thus, to support access to individual developments, parking needs to be supplied. Consider the case for a residential development, where parking supplied in association with the development generates private vehicle trips. Accordingly, when parking bays are supplied with residential units, tenants are incentivized to own a private vehicle and to use that private vehicle for trips. Parking associated with nonresidential development, such as offices, attracts private vehicle trips; that is, it induces tenants and visitors to drive to the land use.

Conventional Calculations

Conventional planning practice is to supply parking on the assumption that individual land uses generate or attract stand-alone parking demand. That parking is typically supplied in accordance with a defined set of criteria based on known parking demand associated with comparable existing land uses. Plainly, the scale of development has a bearing on the parking requirement, and this is another variable for consideration in calculations of parking supply.

Standardization of parking supply in these ways has been aided through the preparation of manuals such as the Institute of Transportation Engineers' "Parking Generation" report in the United States and the New South Wales Roads and Traffic Authority's "Guide to Traffic Generating Developments" in Australia. These and similar manuals have formed the basis of planning scheme requirements for parking associated with new developments, which are applied by approval authorities. These requirements are generally expressed as a number of bays provided on-site per unit of development; for example, bays per dwelling unit or for each 100 square feet or meters of gross floor area.

Common practice is to specify a minimum but not a maximum parking requirement. This is because application of a minimum is perceived to minimize the risk of parking overspill, and therefore the use of bays not specifically intended for use by people associated with a defined land use. In contrast, maximum provisions are not considered to serve a particular planning purpose. Furthermore, some developments may be considered to have a competitive advantage in supplying a generous amount of parking, as this can be attractive for tenants and visitors. These perceptions are changing, though, and are explored in further detail below.

Plainly, application of standardized formulas for parking supply has provided development proponents with a degree of certainty regarding the amount of parking that they should provide. Moreover, it has simplified the process of evaluation by approval authorities, who can simply check whether or not a development conforms to requirements. However, the survey data that underpin the formulas have a number of shortcomings, which can lead to parking supply for a particular development not being responsive to context. These shortcomings include the following:

- Survey data relating to a limited number of sites, meaning the data set is not very powerful
- Survey data having been collected in a unique context, such as suburban locations where land uses are atypically car oriented
- Assumptions that the users of parking are actually visiting the land use that it is associated with
- Reporting parking requirements based on a high percentile period of demand, and only for particular periods in a day (that is, during ultra-peak periods of activity, such as the Christmas shopping period for retail)
- Limited sampling to reflect peak periods, parking accumulation over time, or seasonality of the particular land use

In addition, survey data can be a useful reference for relatively common land uses, such as office or general retail. However, a benchmark for parking supply can be much more difficult to establish for mixed-use or boutique and less common land uses, simply because there are much less survey data (and, therefore, standard requirements) available.

Analysis of Stand-Alone Requirements

In practice, the stand-alone parking demand associated with individual land uses depends on a variety of different factors, and a sound understanding of the urban context is needed to understand specific supply requirements. Relevant land use and transport variables include the following:

- The extent to which user groups—visitors, tenants, residents, and so on—can access the subject land use by modes other than private vehicle. Plainly, this is a function of public transport service provisions, and the walkability and attractiveness for cycling of the built environment.
- Constraints imposed by the local road network, which can either dissuade or limit people from driving to the subject land use.
- The land uses that are nearby, adjacent to, or integrated with the subject land use, as a portion of trade may be "passerby" and not

require stand-alone parking supply. Excellent examples of this are found in town centers and mixed-land-use precincts where a high percentage of trade associated with boutique retail and cafés may be generated by local residences and office developments.

- Effects of trading hours and variable-demand profiles between different, clustered land uses. For example, office developments can generate parking demand within standard business hours, whereas a nearby restaurant may experience heaviest trade and, therefore, parking demand in the evening and on weekends. Under these circumstances, it is much more efficient for at least a portion of parking supply to be shared between the different land uses, based on analysis of when overall demand for parking across the respective developments is at its peak.
- The availability of public parking supply in the area, including on-street parking, because this can offset at least some of the independent parking demand associated with land uses.

Researchers including Donald Shoup, G. B. Arrington and Robert Cervero have highlighted the problems associated with using standardized parking supply rates to stipulate requirements for proposed land uses. Their research has shown that developments within town centers and transit-oriented developments (TOD) require significantly less stand-alone parking supply than equivalent developments in low-density suburban locations. This is for the reasons specified above.

The researchers posit further that oversupply of parking, aside from being spatially inefficient and an unnecessary cost, can induce private-vehicle trips and undermine motivation to use alternative modes, such as public transport, walking, and cycling. This constitutes a poor outcome in a town center or TOD.

Contextually Specific Calculations

While the intricacies of calculating real parking needs are increasingly well known, the resources required to assess stand-alone parking supply requirements and determine a management regime

can be considerable. This tends to present difficulties for approval agencies—especially local governments—that often rely on standardized processes for managing development applications and may not have the necessary skill set to assess each application on its own merits.

On occasion, the development proponent may not be equipped to adequately account for context in defining a reasonable amount of stand-alone or shared parking supply. This is most evident when there is little or no precedent to which to refer, which is more likely when the proposed development is more specialized.

Special Uses and Considerations

There are land uses that attract extraordinary trips, and, therefore, require a bespoke parking-supply strategy. Depending on the special land use, which may be a one-off or irregular event such as parking associated with a concert venue, independent parking supply may be inefficient and undesirable. Sports stadiums provide one example of a use where a highly independent parking supply may be considered desirable, even though it is used infrequently.

In contrast, while weekend farmers' markets in a community may be equally infrequent and as large a generator of parking demand, planning authorities might not consider the markets to warrant independent parking supply. Under these circumstances, temporary parking may be accomplished within open space, with some parking spilling over onto nearby streets and public parking facilities. Some visitors may also attempt to park their vehicles within proximal private parking facilities. This may require institution of a management regime.

Strategies to Justify Reduced Supply

Fees and other regulatory strategies may be employed to help justify reduced rates of parking relative to conventional standards. This is on the basis that these mechanisms help reduce vehicle trip demand and therefore demand for parking. For example, there are well-established parking price elasticities in the literature, and many practitioners would agree that an elasticity between 0.1 and 0.3 would be reasonable to assume. This means that a 100 percent increase in parking fee may lead to a 10 to 30 percent reduction in demand for parking.

Similar parking demand reductions are possible through institution of dwell-time limits. For example, capping permissible dwell time at two hours will help avoid demand for parking by commuters, although such regulations require enforcement to be effective. Pricing and dwell-time limits are not practical for residential land use. This is because tenants have a reasonable expectation to be able to use a bay assigned to their unit when they want to. As an alternative, parking bays can be unbundled from the sale or lease of units, thereby providing tenants with the choice of whether they need or want to buy or rent parking spaces. Unbundling is commonly considered to be an economically efficient method to reduce parking investment for developers, even though it is a relatively unconventional practice.

In general, the complexity of a parking supply and regulation will depend on where a development is located within an urban environment. Reduced parking supply relative to conventions may only be reasonable where residents, workers, and visitors can access alternative means of transportation to offset the reduced supply of parking. These alternatives need to be realistic: for example, they cannot mean significant additional travel time and cost. Otherwise, the commercial appeal of a development can be compromised due to low accessibility.

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See Also: Institute of Traffic Engineers; Mode Share/Mode Choice; Parking Demand; Parking Lots; Parking Planning and Management; Parking Regulation and Enforcement.

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Parking Lots

Parking lots are designated areas where it is permitted to leave personal vehicles in a comparatively safe location, generally for a fee. The level of the fee and the expectation of the length of stay will generally be dependent on the location and purpose of the parking lot. Those that are attached to out-of-town shopping malls, for example, exist to encourage people, especially families or groups, to visit for extended periods, and so fees will be low or even free. Parking lots attached to train stations, meanwhile, are aimed at providing a service for people to return after a number of hours, for example, as part of a daily commute, and so fees are structured so as to be convenient for regular users.

Parking lots may also be used to organize the movement of people within cities or at tourist destinations by gathering vehicles in certain locations so that people can be moved by a form of mass transit for organizational or environmental purposes. In other words, parking lots can have various purposes in addition to the basic one of housing vehicles.

Purpose and Location

In urban areas, in particular, space is at a premium, and if vehicles can be parked along the curbs of streets, traffic may become clogged. This leads to problems with pollution, safety, and inefficient use of time because people find it difficult to find a space near their destination. In some cases, people will be tempted to park illegally or to double park, which will exacerbate the problems for all drivers in the area. Clearly, therefore, it is important for urban planners to ensure that appropriate parking space is provided for residents and visitors. Limited on-street parking space can then be retained for emergency services.

Because urban space tends to be very expensive, it is important to minimize the amount of space occupied by each vehicle. This is generally approached through employing multistory structures and basement designs, both of which can be efficient uses of space. In Singapore, for example, a large proportion of the department stores and malls have extensive basement parking lots that use computerized signage to alert drivers of how many vacant spaces are available on each level and, with a system of green and red lights, exactly where on an individual level a vacancy exists. Regardless



Many of the vehicles in this parking lot at the Cincinnati Zoo in Cincinnati, Ohio, in May 2013 are shaded by a roof made with solar panels; the electricity generated by the panels is used to help power some of the zoo's other facilities. In developed countries, parking facilities are making use of similarly innovative technologies to contribute toward sustainable energy use, while others are using new technologies to reduce labor costs, such as mobile telephone payment systems.

of Singapore's extensive public transportation network, the use of personal vehicles is still popular in the country, especially for family outings and shopping or leisure trips. These trips are more expensive and are regulated further by the use of electronic ticketing during peak-hour traffic periods. The central retail area would quickly become overrun with traffic without such advanced management systems.

In other places, such as in the United Kingdom (UK), it is possible for commercial companies to run parking lots as profitable concerns. This is particularly true in larger cities such as London, where many destinations have no parking spaces attached, and, consequently, visitors are willing to pay quite large amounts of money to be able to take their vehicles with them. This includes service workers, such as plumbers and electricians, who have extensive suites of tools and equipment they need to take with them on calls.

London is a historic city, and much of its development took place at a period when horses or horse-drawn vehicles were the principal mode of transportation. As a result, thoroughfares are narrower than cities developed in the modern age, and there may be important buildings and facilities located in difficult-to-access sites. In areas of particular historical interest, it may be impossible to redevelop the land uses, and so consideration needs to be given to organizing orbital parking lots or imposing pedestrian-only areas for visitors.

In the case of the university town of Oxford, also in the UK, orbital lots are placed at the junctions of arterial routes and the outskirts of the city, and low-cost and frequent buses are available to take the visitors to city-center areas where walking to different locations is quite convenient.

Such precautions are not generally required in cities more recently planned with automobile use in mind. In the case of countries such as the United

States, space in certain cities is not so constricted, and many land uses are able to maintain their own parking facilities.

Many Americans associate the use of their personal vehicles with a sense of freedom and individuality, which has tended to militate against the successful use of public transportation, at least outside the major cities. Suburban and rural life takes place in an environment in which space is more plentiful, and most homes have scope to accommodate one or even several vehicles. In these cases, parking lots are needed at retail or commercial premises to accommodate the vehicles that are necessary to travel there.

Design and Safety

Parking lots can sometimes be dangerous places because they may be open late at night, are easy to access, and offer many places for potential assailants to hide. People walking in parking lots at certain times are vulnerable to personal assault and robbery or attackers wishing to steal their cars once drivers open the doors. In lots in remote or under-observed areas, vehicles may be subject to theft or breaking and entering. Operators of such facilities provide various safety features, such as closed-circuit television systems, alarms, or on-site guards to provide people with sufficient confidence to use them.

For safety and convenience reasons, some parking spaces must be reserved for people in certain categories, especially people with physical disabilities, close to the entrance of the facility. Some lots may offer spaces for dropping off passengers near entrances, which are sometimes known as kiss-and-ride areas.

Because there is a likelihood of wheelchairs or similar equipment being used, spaces designated for people with disabilities will be larger than usual. Space size also varies because of sociological and geographical reasons. In some countries, average car sizes consistently tend to the smaller (for example, Japan) or the larger (for example, the United States) and this has an effect on the space required.

In most of Australia, housing space is relatively abundant and most families have large kitchens and fridge-freezers. This, in turn, leads to the need for large supermarket carts and, hence, greater space required in the parking lot. In situations in which space is constrained, large vehicles may be charged extra or banned from entering.

Payment Systems and Value-Added Services

Parking lots routinely require users to pay for their use, either directly or indirectly, and there must be some system to ensure payment is made. Simple systems include a manned cubicle monitoring entry and exit points. Customers are issued a ticket on entry and then surrender it when they are leaving. Manual or electronic systems determine the length of time that the vehicle has been parked, and, consequently, how much the fee should be.

In countries with comparatively low labor costs, large parking lots may have quite substantial complements of staff. However, people have been replaced by technology in most developed countries. In these cases, an electronic barrier prevents access until a token or keycard is taken or used, and, before leaving, drivers must pay by cash or credit card at the payment machine. Newer payment technologies include mobile telephone payment systems.

The prevalence of reliable mobile telecommunications and comprehensive Internet and network access in many developed countries has meant that previous forms of payment systems, such as coin-operated clockwork machines or pay-and-display systems are becoming obsolete. Similarly, the job of parking meter attendant—a person who patrols an urban environment checking whether vehicles have exceeded the permitted length of stay and issuing penalty tickets when necessary—is also being phased out in favor of technological solutions. However, in most parts of the world, this level of technology is not available, and less efficient manual systems remain in use.

In some upscale department stores and shopping malls, parking lot management may offer a valet-parking service, which means staff park the vehicle for the driver, for a fee, and retrieve it later when the customer is ready to leave. This saves time for the customer, who might otherwise have to spend a considerable amount of time circling around waiting for a space. Valet parking can also provide the most efficient use of existing space because valets can use skillful parking maneuvers and venture into dark or remote locations ordinary customers would not always be happy to use.

Valet parking is one of the more obvious forms of value-added services that can be offered at a parking lot that improve attractiveness for customers and profitability for the lot operator. Another service is automobile washing and care, often provided by a

subcontractor leasing space in the lot and cleaning vehicles while customers spend time in the adjacent facility. In very busy cities such as Bangkok, the car cleaning area may be the only part of the lot that has any vacant spaces.

Particularly in urban space in developed countries, providing parking lots sufficient to the needs of an ever increasing population represents a significant expenditure of resources. Certain critics have noted that easy and free or low-cost parking encourages people to own and use personal vehicles rather than mass transit, walking, bicycling or shared-transport options. This results in additional pollution and street congestion. Making conditions convenient for automobile users often makes conditions less convenient and less safe for other road users, including cyclists, pedestrians, operators of mobile vending trolleys, emergency vehicles, and so forth. This is not necessarily an egalitarian solution.

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See Also: Parking Design Requirements; Parking Regulation and Enforcement; Parking Revenue and Collection; Parking Structures.

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Parking Planning and Management

Parking management is a critical responsibility of local transportation policy shared between public and private actors. Parking is one of the few transport policies that are under the direct control of

cities. Managed effectively through regulation and pricing, parking can improve traffic flow, enhance the pedestrian environment, encourage transit use, and raise revenue for public investment. In recent years, cities have experimented with innovative ways to improve the performance of their parking systems, but parking remains a largely unexplored area for transportation and land use planning. Therefore, it represents an extremely promising area for improving transportation demand management, increasing the quality of the built environment, enhancing nonautomotive modes, and raising revenue for public investment.

Parking can broadly be defined in two categories: off-street and on-street. Most off-street parking spaces in the United States, and much of the off-street spaces around the world, are required by minimum parking requirements in zoning codes. The public justification for regulating the supply of parking focuses on the false idea that parking supply should accommodate unlimited demand. In order to prevent spillover parking—where drivers park in residential neighborhoods when visiting nearby businesses—cities started to require on-site parking for all land uses and developments beginning in the 1940s. These minimum accessory parking requirements were quickly adopted by cities throughout the United States and around the world.

Off-Street Parking

Local zoning codes regulate the supply of off-street parking. It is very common, and nearly universal in the United States, for cities to enforce minimum parking requirements for all types of land uses. A typical residential requirement is one parking space per bedroom or one parking space per unit. For commercial properties, the requirements vary substantially, but three parking spaces per 1,000 square feet (93 square meters) is common. In most cases, parking required through the zoning code or use permits must be accessory spaces, or located on-site. The steady expansion of required parking has left urban and suburban cities with massive oversupplies of parking spaces, and most of these spaces sit empty most of the time.

Required parking increases the cost of goods and services for everyone, regardless whether or not they drive. By requiring parking on-site, the cost of building and maintaining parking is bundled in retail prices and rents. Researchers have

demonstrated how parking requirements increase the cost of housing, which is a major concern for affordability. Basic fairness is challenged when low-income families who are unlikely to own a car must pay for an abundance of parking they do not use.

On-Street Parking

While traditional parking management has focused on the supply aspects of parking, recent experiments have shifted focus to the role of prices to manage demand. Consider the case of street parking. Whether street parking is free or metered and paid, motorists often think that there is simply not enough of it. More accurately, there is excess demand for parking when the price is too low.

When all parking spaces along the curb are full, any drivers who want to park are “forced” to drive around searching for a space. This is known as “cruising for parking,” and many studies have estimated that in some neighborhoods drivers cruising for a space can represent as much as 40 percent of total traffic. Driving around looking for a place to park is excess travel once drivers have already reached their destination. Cruising for parking is a failure of the commons, where no one manages the spaces for the greater good. In a commons, many people acting in rational self-interest leads to overconsumption and overall costs to society. In this case, the individually rational action of cruising for parking causes tremendous damage to the environment, traffic congestion, street safety, and effective management of local transportation systems.

Municipalities are able to regulate prices of parking to promote occupancy rates. Unlike a coffee shop or restaurant, where customer turnover is a sign of success, properly priced parking achieves occupancy targets. However, what motorists really want is cheap or free parking, and there is ample evidence that they are willing to drive astonishing lengths in order to find a space that is just right. A review of cruising-for-parking studies suggests that in many urban neighborhoods, the share of traffic just driving around looking for a place to park averages around one-third of total traffic.

Theory

Theory predicts that cruising for parking is the result of underpriced curb parking relative to demand. Once drivers reach their approximate destination, they have the option of parking off-street, usually in

off-street spaces developers are required to build, or searching for a curb space. In areas where the cost of off-street parking exceeds that of on-street, drivers have an incentive to cruise around to find a space. Drivers will cruise for a space until they either find a space or their marginal value of time equals the money saved by parking on the street. In the latter instance, drivers will either choose to park off-street or abandon their initial trip destination. Under these circumstances, if the price of curb parking is raised to equal or exceed the cost of off-street parking, drivers will have no incentive to search for parking.

The elasticity of demand for parking is dependent on factors beyond parking location. Studies demonstrate that the demand for parking varies by time of day, perceived safety, weather, and other aspects. While many businesses and drivers voice concerns about the economic effects of increased parking charges, there is no scholarly evidence that suggests that parking management has negative influence on local economic activity. To the contrary, the few cities that have raised the price of parking have realized increased economic activity. This is especially true in places where the additional revenues raised from increased parking charges are used to improve local public services in the affected neighborhoods. Examples of public services paid for with meter revenue include public safety, sidewalk cleaning, trash removal, and other similar improvements.

Evidence

Managing the curb to maintain occupancy targets of one open space per block, or 85 percent occupancy, is recommended in the literature and called performance-based pricing. Many cities are using these standards in practice. In San Francisco, the U.S. Department of Transportation sponsored a project through its Value Pricing Pilot Program to evaluate how well prices work to manage demand for parking. The project, called SFpark, used seven pilot zones where sensors monitored the occupancy of curb spaces. Then, every six weeks, the city used the collected data to adjust the price of curb parking higher if occupancy exceeded 85 percent, or lower if occupancy fell below 85 percent. During the initial pilot test periods, the price of parking increased in some areas and declined in others through an iterative process of trial and error.

The city of Seattle, Washington, has also used prices to manage parking demand. In 2011, Seattle

used data from parking pay stations to adjust parking rates. Researchers studying the effects of the Seattle project found that drivers' sensitivity to changes in the price of parking vary by time of day. Lunch hours, for instance, feature the highest parking demand and require different pricing strategies than other hours of the day.

Contracting

In recent years, many cities have contracted out their parking-meter management in exchange for up-front payments. In 2008, the city of Chicago leased 36,000 street parking spaces for a 75-year term, in exchange for an up-front payment of \$1.15 billion. The city now features some of the highest meter-parking charges in the nation. While the merits of such privatization deals are contested among scholars and public officials, other cities are exploring these types of contracts to monetize their parking resources. From a traffic perspective, higher meter rates are desirable for reducing cruising and making other modes more attractive.

Conclusion

Parking management through pricing and regulations offers cities tremendous opportunities to shape and reshape communities. Minimum parking requirements are perhaps the most pernicious aspect of transportation systems, because they steadily increase the supply of parking without respect to demand or need. By flooding the market with required parking, cities ensure that driving is heavily subsidized, even by those without cars.

Excess off-street parking supply is made worse through underpriced curb parking. Meters that are too cheap or, as in many cases, free cause excess driving while motorists look for curbside spaces, even if off-street parking is available nearby. To better manage their parking assets and raise revenue, many cities are considering contracting the management of street parking to private companies. These contracts are often unpopular with the public, though, and need to be carefully drawn.

Curb parking is also heavily regulated, but it is often given away for free or close to free. Underpriced curb parking leads to excessive cruising around to search for a place to park on the street. This cruising distracts drivers, congests traffic, harms the pedestrian and cyclist environments, and wastes time. Ultimately, underpriced curb parking

also represents lost opportunity to raise public revenue that can be used for valuable public services.

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See Also: Economics of On-Street Parking; Parking Demand; Parking Finance; Parking Generation Rates; Parking Lots; Parking Structures.

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Parking Regulation and Enforcement

Government has created parking regulations to keep streets in good order, secure roadways for emergency vehicles, protect public safety, and ensure the efficient use of this often scarce resource. Such measures include requiring drivers to pay for parking; prohibiting them from occupying one space for too long, reserving places for certain drivers or vehicles (for example, residents, disabled drivers, electric vehicles, etc.), or barring drivers from leaving their vehicles in certain locations. Although these regulations apply mostly to public parking, laws also exist to protect private parking spaces from being usurped by drivers who do not have the permission of the property owner to occupy an off-street space.

Despite the fact that parking laws usually have a rationale that withstood public scrutiny before enactment, there are always drivers who do not respect parking regulations—out of either negligence or willful disobedience. Parking enforcement is therefore designed to ensure drivers respect the laws by allowing the appropriate authority to sanction the drivers (or vehicle owners) who fail to comply with the law. While many drivers act in accordance with parking regulations, other drivers comply only with the threat of punitive action—either through

the act of being publicly reprimanded or sanctions that cause substantial inconvenience and/or financial damage.

Enforcement Mechanisms

Parking enforcement mechanisms vary by purpose. Some jurisdictions allow parking and law enforcement officers to give written warnings that carry no financial penalty. The more commonly used tool, though, is the issuance of parking tickets or citations to penalize an owner of a vehicle that is parked illegally. Parking enforcement personnel have the legal authority to issue tickets to motor vehicles, which they usually leave under a windshield wiper of a vehicle.

These tickets record identifying features of the vehicle (for example, license plate, make, model, and color), the violation(s) that merited the citation, and the date, time, and location. The citing authority also typically mails a copy to the address of the vehicle's registered owner to ensure a proper notification of the citation. A responsible party is required to pay the fine or can bring the case to a court for resolution.

The monetary fine of the citation must be high enough to dissuade most drivers from parking illegally. While this amount is sometimes determined arbitrarily, based on whatever amount sounds punitive yet politically acceptable to the officials responsible for enacting parking regulations, more methodological approaches do exist.

In the case of paid parking, for example, fines can be set by dividing the hourly price of parking by the probability that a violating car will receive a ticket within one hour. If the price of curb parking is \$3.60 per hour and the hourly probability of being caught is 2 percent, the fine is \$180 ($\$3.60/\text{hour} \div 0.02/\text{hour}$). This method is designed to have drivers eventually realize that getting a citation is less desirable than just paying for parking in the first place, either because the fine is very high or because they are very likely to get a ticket.

Public officials can also increase the likelihood that an illegally parked car will receive a citation by increasing the number of parking enforcement personnel. Many responsible agencies may find increasing staff too costly, especially if the revenue from parking fines does not cover the cost of enforcement. Alternately, an agency can increase the productivity of personnel by, for example, switching

from hand-written tickets to electronic handheld parking ticket printers that speed up the process of issuing tickets. Some parking enforcement authorities also use vehicle-mounted camera systems in conjunction with license plate recognition to issue citations. Speeding up the process of issuing tickets allows enforcement personnel to cover more ground, thereby increasing the probability that a scofflaw driver will receive a parking violation.

Some parking violations require more immediate remedial action than ticketing. Parking enforcement personnel often have the discretion of towing vehicles deemed a threat to public safety (for example, parked in a traffic lane, or blocking a crosswalk or fire hydrant) or that are appropriating spaces reserved for certain drivers, such as disabled people.

Drivers who chronically do not pay their parking tickets may also have their vehicles impounded. Impounded vehicles are usually brought to a tow truck company's property or a public tow yard, where vehicle owners must go to retrieve their vehicles. Drivers must often pay high administrative fees related to the towing, storage, and processing of the vehicles. These fees are usually higher than the parking fines for the violation.

Another tool used in parking enforcement—particularly to deal with habitual parking offenders and nonpayment of citations—is the use of wheel clamps. Also known as “parking boots,” these metal devices are designed to clamp onto a vehicle's wheel to prevent the driver from moving the vehicle or from removing the wheel itself. Drivers must pay their parking tickets before the enforcement agency will unlock the wheel clamp. The use of the boot is also a way to reduce cost, because personnel no longer need to wait for tow truck drivers.

Compliance

The parking enforcement field is typically rife with conflict. Occasionally, enforcement personnel encounter drivers when issuing a citation. How these personnel interact with drivers depends on the context, but these interactions are usually stressful for both parties. Parking enforcement personnel are subjected to verbal abuse and, occasionally, even physical threats, which can potentially impact their physical and psychological well-being. This can increase employee turnover and harm job performance, while lowering the probability of the public receiving tickets.

Although a perfect compliance rate is not expected, setting compliance goals can allow decision makers to determine whether their enforcement strategies are working as intended. The rate of compliance for a given regulation can be measured by conducting surveys of parking behavior, including the percentage of cars parked illegally. Technological interventions, such as in-pavement sensors, can determine in real time whether drivers have parked their vehicles too long or without having paid.

Information obtained from such technology can be relayed to parking enforcement officers, who can use it to seek out vehicles in violation and issue them parking citations. By increasing the probability that personnel will find cars violating parking rules, such technology could help keep parking enforcement costs from becoming too great a financial burden for public agencies.

Levels of Enforcement

Public officials have varying perspectives on an acceptable level of enforcement, based on public opinion as well as their personal judgment. Public pressure from merchants, residents, drivers, and the media can influence how parking enforcement tools are used. Setting parking fines is particularly controversial for paid parking because the public often believes that parking should be free.

The public has used equity arguments to limit parking enforcement—particularly for the level of fines. For example, a rich or poor driver pays the same amount regardless of the circumstance, which means that a fine will have a disproportionately severe effect on lower-income drivers and potentially no impact on wealthier drivers. Under public pressure and calls for fairness, elected officials have frequently avoided raising parking fines to levels that will improve compliance.

There are ways that public officials can reduce conflict and improve equity in the field of parking enforcement. With respect to paid parking, officials can allow drivers to pay for more time than they plan to use and receive a refund if they vacate their space early. This reduces the likelihood drivers will underestimate their stay and achieves paid parking's primary goal: creating turnover. It also reduces drivers' anxiety about paying for parking when they may not know in advance how much time they will need and their destination is too far away to refill the meter.



A police car parks near a solar-powered pay-and-display parking meter in Houston, Texas. Vehicle-mounted camera systems, license plate recognition, and handheld electronic parking ticket printers are among the new technologies in parking enforcement.

Another way to increase compliance without being heavy-handed is through the introduction of graduated parking fines. Under this system, the first ticket carries a relatively low fine, but the monetary fine increases with each subsequent ticket. This approach treats those drivers who regularly violate parking laws more harshly than the driver who might occasionally do so. To positively influence the politics of parking enforcement, an agency could, for example, dedicate some of the parking-fine revenue to the neighborhood in which the driver received a ticket. This mechanism likely increases support for parking enforcement.

Such funds could be used to pay for public services or improvements, much like parking meter revenue in a parking-benefit district. Legally, the fine also becomes a remedy for an infraction committed by the driver, which tends to have local effects either on parking supply or on safety. Moreover, dedicating

some of the revenue can reduce conflict between enforcement personnel and drivers. Some of drivers may feel less bitter if they know their fine will be used to improve an area and their future experience there.

Parking enforcement is intended to change driver behavior, manage parking as a resource, and raise revenues for municipalities. Technology can improve the compliance of drivers, but policies can also do so. Ultimately, though, parking enforcement depends on policies adopted by decision makers and which the public supports.

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See Also: Economics of On-Street Parking; Parking Demand; Parking Planning and Management; Parking Revenue and Collection; Traffic Laws and Enforcement.

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Parking Revenue and Collection

Most automobile parking is free to the motorist, yet is never free to the supplier. Many smaller cities and suburban areas have explicit or implicit policies to keep parking free to the user, but in central districts of larger cities and other locations with high

demand, parking pricing is common. Parking pricing is important, both as a demand management measure and, secondarily, as a source of revenue to offset costs incurred by parking providers.

In the case of publicly provided parking, that revenue can be used for enhancing both parking facilities and the destinations that draw motorists in the first place. Many parking fee-collection systems have been developed since the advent of the automobile, and these systems are evolving at a rapid rate.

Attended Parking

Attended parking represents the earliest form of paid parking. A human attendant serves as both cashier and enforcement agent, ensuring that all motorists parking in a controlled-access lot or garage pay an appropriate amount. In larger facilities, the attendants are posted only at the exits; automatic gates at entrances require entering motorists to take a time-stamped ticket, which must be presented with payment to the attendant before exiting the facility.

Some newer facilities have eliminated human attendants by using magnetic strip tickets to record time entered; before returning to their car, drivers must pay for their time at a machine that validates the ticket. Drivers are then given a grace period of several minutes so that they can return to their cars, drive to the exit, and insert the card that will open an automated exit gate.

Valet parking is a special case of attended parking. In this case, attendants park the vehicle for the motorist and then retrieve it when the motorist is ready to depart. This arrangement has advantages for both motorists, who can leave their car at the main entrance of an establishment, and for the establishment, which can utilize relatively remote parking, rather than needing to provide all parking on or near the site. Attendants are also able to park cars in a more space-efficient manner than individual drivers, so less total parking space may be needed. Operating costs of valet parking are higher than other forms of attended parking, though, because both the number and skill level of the attendants are higher.

Parking Meters and Pay and Display

The parking meter debuted in 1935 in Oklahoma City, Oklahoma. A coin-activated timer adjacent to an on-street parking space indicated to enforcement agents that an appropriate payment had been made, and time limits on the meter ensured

turnover of parking spaces. Parking meters soon became a common sight in major cities, and they remain the most common payment technology for on-street parking.

“Pay-and-display” multispace parking meters first appeared in the 1950s. Early coin-operated machines provided the customer with a receipt that was displayed on the customer’s dashboard. Because one pay-and-display machine can serve several on-street parking spaces, the capital investment and maintenance costs are potentially reduced for the local authority, although individual pay-and-display meters are more costly than single-space meters.

Another advantage of pay-and-display systems is that they prevent drivers from taking advantage of parking meters that have time remaining, since the proof of payment stays in the paying driver’s vehicle. More recent machines also accept multiple forms of payment—coins, currency, credit cards, and smart-cards—and some are able to provide change.

There are also off-street applications of pay-and-display. Major institutions (for example, universities and hospitals) often deploy pay-and-display systems. Visitors typically purchase time and receive a receipt from a machine to display in their cars, eliminating the need for an attendant at either entry or exit. Frequent parkers (for example, employees) can be allowed to purchase a long-term-parking tag or sticker, which is displayed on the vehicle itself and enables those users to avoid stopping to check in or out on a daily basis. Given these features, pay-and-display systems are much more efficient for both the customer (in terms of time) and the operator (in terms of labor costs).

Newer pay-and-display machines provide operators with remote access to their machines via wireless communication, enabling real-time monitoring for failure of the machines or tampering. They also enable credit-card authorizations and other forms of electronic payment in real-time, and, perhaps most importantly, they monitor parking demand on an ongoing basis and can reconfigure the rates and customer interface display remotely.

Emerging Payment Technology

A number of cities have implemented in-vehicle payment-and-metering devices that provide the motorist convenience of paying for parking through stored-value technology. The driver starts the meter (typically displayed on the car’s dashboard) upon

parking, and the device deducts from preloaded amount of money digitally coded into the device. If parking rates vary by district, the motorist may need to indicate the parking rate, as well as the start and end times. Value can be replenished electronically. In addition to being more convenient for users, in-vehicle payment systems have the added benefit that the driver is charged only for the actual time spent.

In the larger economy, new technologies have dramatically changed the way small payments are made in retail and service establishments. Key among these new technologies are contactless smart cards (CSCs) and mobile phones enabled with near field communication (NFC) technology. These smart cards and NFC phones have been increasingly used for transit-fare collection since the 1990s, and they are playing an increasing role in parking-fee payment and collection.

Fee calculations are performed with bar code and magnetic-ticket processing, thereby eliminating paper tickets and currency handling, and reducing field service and maintenance costs for parking meters and other payment machines. Moreover, wireless electronic access control systems do not require on-site power or network communications, although still providing real-time data about parking usage.

Pay-by-phone is becoming more common as smartphone applications for secure payments become ubiquitous. By replacing much of the technology surrounding paying for parking with users’ cell phones, substantial capital and operational savings are possible. In addition, parking rates can be adjusted quickly, enabling parking operators to adjust parking rates to match fluctuating demand.

Many emerging payment technologies have been brought together by the City and County of San Francisco in an advanced parking management system known as SFpark, launched in 2011. The SFpark system uses sensors, smart meters, and demand-responsive pricing to collect and distribute real-time information about where parking is available, enabling motorists to more quickly find open spaces. To help achieve a desired parking availability of 15 percent by zone or block, SFpark periodically adjusts meter and garage pricing up or down to match demand. As of May 2013, there had been 10 such pricing adjustments. Rates can vary by block, time of day, and day of week.

Demand-responsive pricing encourages drivers to park in underused areas and garages, reducing demand in overused areas. Motorists may pay by cash or electronically, including by cell phone. The overall aim is to use real-time data and demand-responsive pricing together to readjust parking patterns so that parking with a location and price acceptable to a given motorist is easier to find.

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See Also: Parking Demand; Parking Enforcement; Parking Lots; Parking Regulation and Enforcement.

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Parking Structures

The multistory parking garage or car park is a fundamental element used in urban and transportation planning in many countries in the world because it provides a relatively compact way to store a large number of automobiles. Although most modern parking garages use straightforward, rectangular designs, they differ in major ways from most buildings because of the weight of the automobiles they house and the fact that those automobiles will be moving through the structure. From a design perspective, open parking structures must be designed to allow efficient snow removal and drainage, and closed structures must adhere to strict specifications regarding ventilation.

Parking structures are seldom constructed in a vacuum, and so they can have major impacts on the areas in which they are located, affecting vehicle and pedestrian traffic, security, and aesthetics. Therefore, the size, location, and appearance of

parking structures should be planned as part of an overall urban or suburban design.

History

Although a few parking mass garages were built early in the 20th century, elevated parking structures did not start to become common until the 1920s, when the number of automobile owners had increased substantially, and more people were using their cars for transportation into urban areas. The familiar rectangular, multistory concrete structure with ramps providing access was well-established by the end of that decade, and some structures were quite large. For instance, the Autorimessa in Venice, Italy, designed by Eugenio Miozzi, had spaces for 2,500 cars.

One difference between these early parking garages and those designed today is that the early structures were usually enclosed, like warehouses, and often embellished with elaborate exterior decoration. Although some were notable in aesthetic terms, they had limited ventilation, allowing for the dangerous buildup of carbon monoxide within the garage.

In the 1950s, different patterns of parking structure location evolved in Europe and the United States. In European cities, many of which had been devastated by World War II bombs, a typical model included a pedestrian zone in the central downtown area, with multistory automobile garages built around the perimeter. In 1963, the English civil engineer Colin Buchanan predicted that the car park would become an expected part of destinations, including workplaces and shopping areas.

In the United States, rapid suburbanization and the growth of shopping malls also made planning for parking an important consideration in new construction. In fact, the term *parking center* was once proposed for what is now called a shopping center, because it was assumed that the adequate parking provided would be part of the attraction of shopping there.

Richard Neutra suggested the construction of open-air car parks in 1940, but the first to open for business was in 1948 in Miami, a Bauhaus-inspired, split-level structure designed by Robert Law Weed. Without the ventilation concerns of previous car parks, as well as lower construction costs, the open-air model soon became the norm for new car parks.

A later innovation was the development of mechanical garages, such as Speed-Park in New York City. Built in 1961, it provided fully automated parking and retrieval for 270 cars using a system of elevators. Although an automated system could fit more cars into the same amount of space, construction and maintenance costs tend to be higher, and this design is far less common than garages with ramps that allow drivers to get to and from their parking places. Another innovation was the integration of parking into urban residential buildings, such as Chicago's Marina City, a downtown apartment complex constructed in 1962.

Planning and Policy

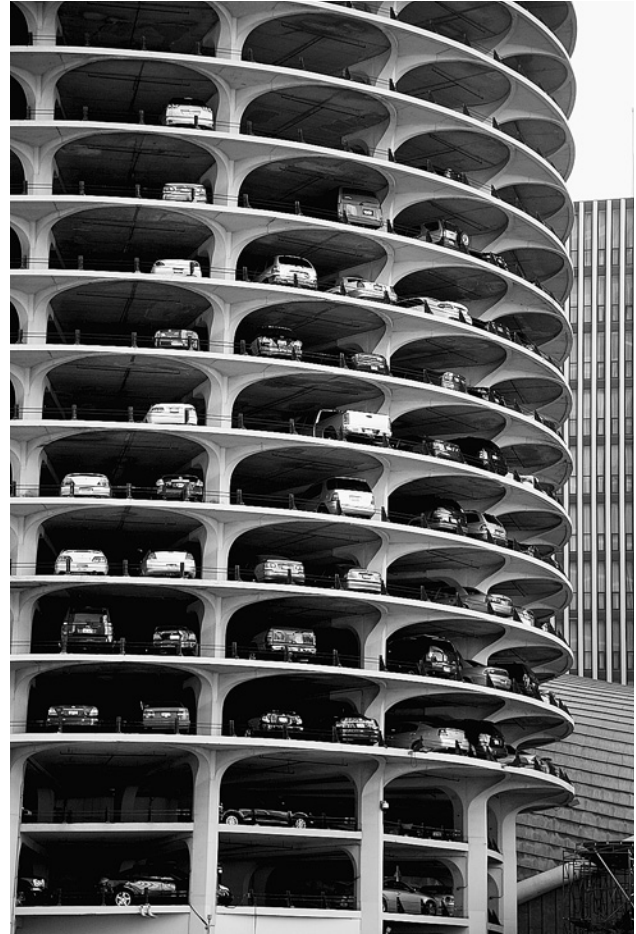
Author Todd Litman has found that the typical car is parked an average of 23 hours per day and uses several parking spaces per week. To accommodate these mostly motionless vehicles, parking facilities now constitute a major type of land use. The question in most parts of the world is not whether to plan and design for automobile parking, but how to do the best job for a given circumstance.

The location of parking spaces can be as important as the number of spaces available in terms of resident or patron satisfaction, and different strategies can be used to increase parking efficiency and/or reduce parking demand.

Planning for parking, including the location of car parks, how large they should be, and the amount to be charged (if any) for their use, should be part of an integrated environmental design. For instance, shoppers often overlook the availability of open-air garage spaces because they are less immediately visible than on-street parking. However, many would use the garage space if adequate signage directed them there.

Placement of garages near the fringe of an urban area, with provision of mass transit into the city center if the distances are great, can be more economical than providing parking within the central business district. Such location of parking structures can also reduce traffic congestion and air pollution in the city. However, drivers may need to be educated about their options, and pricing strategies can also be used to encourage them to use peripheral garages rather than driving directly to their destination.

The Victoria Transport Institute (in Victoria, British Columbia, Canada) offers a table of



This open-air parking structure is built into the residential towers of Chicago's Marina City, a downtown apartment complex constructed in 1962. The complex inspired later parking structures built into large developments in the United States.

hypothetical cost recovery prices for different types of facilities, using estimated costs for land, construction, and ongoing operation and management. For instance, for a four-level structure in a central business district, the monthly rate for cost recovery alone would be \$150, versus \$135 for an urban three-level structure, \$75 for an urban surface lot, \$115 for a suburban two-level structure, and \$35 for a surface lot built on free land.

Of course, other factors may also be used to set prices. When demand for parking outstrips supply, as in many large cities, fees can be set at a high rate and the parking structures will still be relatively full. Higher-than-recovery pricing can also be used to shape behavior. For example, the Victoria Transport Institute cites a 1993 study showing that relatively

small increases in parking fees could result in substantial reduction in the number of vehicle trips to a location, particularly if alternative means of transportation are available.

Finally, aesthetics and environmental impact should also be considered. A compact parking structure may be more appealing than a large expanse of paved lots, and it allows more of the land area to be reserved for parks or other purposes.

Design

The design of a parking structure should be based on the requirements of the expected users. Will they use the facility every day, as in employee or resident parking, or will many users be infrequent guests of the facility, as in shopping mall parking? In the latter case, good wayfinding aids (signage, visibility) will be necessary, while in the former case, they will be less important. If the users are short-term parkers, for example, they may be more interested in the ease of finding a space and exiting quickly, and so planners may reserve some of the most convenient spaces for visitors (often charging a higher fee for those spaces) while reserving more distant spaces for residents or employees.

Another consideration is whether to allow for one-way or two-way traffic flow through the facility. One-way traffic makes it easier for drivers to get in and out of parking spaces, and requires less space be devoted to the driving aisles, while two-way traffic offers better visibility, safer pedestrian access, and a more natural pattern of driving—as well as eliminating the possibility of a driver accidentally turning the wrong way into one-way traffic.

Structures designed for one-way traffic generally have angled spaces, while those with two-way traffic generally have spaces perpendicular to the aisle. Normally, angled spaces are arranged to point toward the exit. New buildings in many countries are required to include a number of spaces for people with disabilities, and these must also be integrated into the structure design.

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See Also: Airport Parking and Ground Transportation; Automobile Culture; Economics of On-Street Parking; Integrated Transportation and Urban Land Use Planning Models; Parking Finance; Parking Lots;

Parking Planning and Management; Urban Sprawl Versus Compact Development.

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Particulate Matter

Particulate matter (PM) consists of a complex combination of organic and inorganic substances in the form of extremely small particles and liquid droplets, including uncombusted fuel, acids (such as nitrates and sulfates), dust, and metal fragments, and represents a hazardous by-product of the combustion process. Particulate matter also varies in size, ranging from some particles that can be seen with the naked eye, such as dust and smoke, to particles so tiny that they can be identified only with an electronic microscope.

Particle size is an important factor because it is directly linked to PM's potential for causing health problems. Particles with a diameter smaller than 10 micrometers can have the most serious health effects because they can pass through the throat and nose and enter the lungs. The U.S. Environmental Protection Agency (EPA) classifies PM into two families, according to size: "inhalable coarse particles" and "fine particles."

The “inhalable coarse particles” group includes PM with a diameter that ranges between 10 micrometers (μm) and $2.5\ \mu\text{m}$ and is generally referred to as PM₁₀. The “fine particles” group includes PM with a diameter smaller than $2.5\ \mu\text{m}$ and is designated PM_{2.5}. In comparison, a human hair is on average $70\ \mu\text{m}$ in diameter, making it seven times larger than the largest PM₁₀ particle and 30 times larger than the largest PM_{2.5} particle.

These particles, as mentioned above, can also be made of a wide range of chemicals. The composition is determined by their origin, which brings about a further classification of particles: primary and secondary particles. Primary PM is emitted directly from a source, such as fires, fossil fuel burning, construction sites, etc., or is formed by abrasion. The particles’ composition depends on their source; for example, particles originated by the interaction between the wind and rocks or the ground tend to consist of mineral oxides, while particles originated from sea spray are made of mostly magnesium, sulfate, organic compounds, calcium, or potassium, depending on the seawater composition.

Secondary PM is the result of the oxidation of primary gases in the atmosphere, which converts them from a gaseous phase to a subsequent condensed phase. Examples include nitrogen oxides and sulfur dioxides emitted from vehicles or power plants. Secondary particles may have an anthropogenic origin and form from gases derived by the combustion of fossil fuel or biomass burning, or a natural origin, such as from the photo-oxidation of natural volatile organic compounds (VOCs).

Other important constituents of primary and secondary particles can also be organic matter (OM) originated from anthropogenic (human-made) or biogenic sources, and elemental carbon (also known as “black carbon”). The secondary fraction of these two aerosols is a result of combustion products of internal combustion engines and has proven adverse effects on human health.

Sources

PM can be characterized by dividing it into the following categories by source. Particulates from vehicle exhaust emissions include particulate matter that is generated by vehicles, and this can be subdivided into two categories, primary emissions and secondary emissions. Primary particulate emissions are a direct result of the inefficient vehicular

combustion process; a small fraction of particulate deposits on the surfaces of the exhaust system, and it is then incorporated in the exhaust gases and emitted into the external environment. Primary PM emission rates generally decrease with increasing vehicle speed, when fuel combustion becomes more efficient, and are greater for diesel-fueled vehicles. Secondary particulates are formed in the immediate atmosphere from the condensation of exhaust vapors or by atmospheric chemical reactions.

Particulates from vehicular nonexhaust sources include a wide range of sources, which are mostly associated with turbulence/resuspension generated by vehicles, and the deterioration of vehicle components. The largest portion of PM originates from these activities. Their resuspension is dependent on weather conditions, such as precipitation, and therefore has a seasonal component, with peaks during dry months. Studies carried out by various researchers demonstrated that vehicle-induced turbulence is a contributory factor in the resuspension of particulate matter. This fraction of PM is mainly linked to road surface material, such as the wear of tires during braking and skidding, or the deterioration of brake linings during braking and road abrasion. The generation of coarse particulate from these sources increases with the vehicle speed.

A smaller fraction of particulate originates from other anthropogenic sources, such as domestic heating and industrial processes, as well as larger amounts generated by construction activities and mining.

Primary marine aerosol (sea salt) is among the largest contributors to coarse particulates originating from natural sources in coastal sites. This would also indicate wind speed as the main weather variable responsible for higher concentrations of coarse particulate from sea salt; higher wind speeds may result in higher concentrations.

Health Effects

Particulate matter has detrimental effects on human health and the environment, which vary according to size and composition of the particulates. With regard to adverse effects on human health, these are difficult to quantify because the wide range of sources of PM, both natural and anthropogenic, makes the nature of particulate matter highly varied. The health effects of PM depend on a wide

range of factors, which can be broadly grouped under the following headings:

Composition. Fine particles may belong to primary or secondary particulates, and they are comprised substantially of sulfates and nitrates, generally in the form of ammonium salts, together with organic and elemental carbon and a range of trace metals. These particles, along with the chemicals transported on their surfaces, can be highly acidic and potentially a source of lung inflammation upon inhalation.

Particle size. This is a key factor that determines exposure and human dosage. G. Oberdörster observed that particle surface area and dosimetry parameters, such as deposition, clearance, retention, and translocation and dissolution of inhaled particles in and to different lung compartments, were important for the persistence of particles in the lung and correlated with adverse pulmonary effects. He also completed a series of epidemiological studies, which have shown that ultrafine particles are causally involved in adverse responses seen in sensitive humans, such as the elderly with preexisting respiratory and cardiovascular diseases.

Epidemiological studies have shown a correlation between environmental particulate air pollution (PM₁₀) and a range of endpoints of lung morbidity and mortality, and an ultrafine fraction of the PM₁₀ particles is considered to be the principal mediator of these effects. Researchers have observed that with normal nasal breathing, larger particles of aerodynamic diameter between 10 and 100 μ m tended to be deposited in the extrathoracic part of the respiratory tract; particles in the range 5 to 10 μ m were deposited in the proximity of the fine airways; and fine particles (less than 2.5 μ m) tended to be deposited in the distal lung airway and airspace.

Length of exposure and dosage: a noticeable increase in lung cancer mortality has been found with even a small increase in particulate air pollution, and positively associated exposure to fine particulates with death from lung cancer and cardiopulmonary disease. A connection has been found between acute respiratory effects and exposure to PM.

A positive connection between long-term exposure to PM and lung cancer, as well as

cardiopulmonary mortality, has been proven. Chronic rat inhalation studies have shown that a number of different particle types can induce significant adverse effects, including impaired lung clearance, chronic pulmonary inflammation, pulmonary fibrosis, and lung tumors.

Exposure to particulate matter has been linked to acute reactions, such as irritative bronchitis (or industrial or environmental bronchitis), and chronic reactions, such as chronic bronchitis and pulmonary emphysema. Several studies carried out in different parts of the world resulted in a clear correlation between exposure to PM and increased respiratory, cardiovascular, and lung cancer mortality rates.

Environmental Effects

Effects on the environment can be broadly grouped under ecosystem damage, urban environment damage, acid rains, and visibility impairment. The deposition of the fine fraction of particulates has detrimental effects on the environment because of the high percentage of sulfates in this pollutant. Fine particulates can travel long distances with the wind, and primary and secondary particles that originated in an urban environment can impact distant ecosystems by settling on ground, vegetation, or water. This phenomenon could result in an increased acidity of surficial aquifers (lakes and streams) and into a variation of the nutrient balance in coastal waters and large river basins.

The deposition of fine particulates can also have an impact on sensitive forests and farm crops; mineral acidic dust may directly damage leaf tissues by corroding them, or indirectly have an adverse effect on plants by altering the soil pH and depleting the nutrients in the ground. The dust on the leaves can also affect the energy exchange between vegetation and the atmosphere by reducing the amount of light available for photosynthesis. As such, agricultural and natural ecosystems may experience reduced productivity or a disruption of nutrient cycles, which may result in the decimation of sensitive animal and vegetable species.

In urban environment damage, the high percentages of sulfur dioxide (SO₂) and nitrogen dioxide (NO₂) in the chemical composition of fine particles have a great impact on construction materials and paints. As it was reported by the National Research Council in 1979, primary and secondary "acidified"

particles may have a devastating effect on the surfaces of buildings and monuments, causing damage and soiling and decreasing the aesthetic appeal of such structures. PM aggravates the degradation of structures that typically arises from long-term exposure to natural agents, such as wind, sun, temperature, and humidity fluctuations. Acid-forming aerosols have been reported to damage various building stones and cement products, and to cause discolorations, and loss of gloss and thickness of the paint film layer, both of which may have serious economic consequences.

With acid rains, SO_2 and NO_x (nitrogen oxides) are among the pollutants that can react with water in clouds to form acid rain. SO_2 can react with water vapor and sunlight to form sulfuric acid, while some of the nitrogen can react with water to form nitric acid. These reactions are slow to complete, and they may take place while the polluted mass of air is pushed by wind to locations that may be hundreds of miles away from the pollution sources. As such, acidified primary and secondary particles originated in an urban environment can impact distant ecosystems, causing acidification of lakes and streams and damaging sensitive forest trees and soils.

Acid rain is also very harmful to the life in the water, polluting surface water and then causing the death of sensitive aquatic fauna. In urban environments, acid rain contributes to the decay of building materials, sculptures, and paints. Even mist and fog can be acid; pollutants may be removed from the air in the form of condensed droplets saturated with chemicals such as sulfur dioxide and nitrogen oxide, which can turn out to be more strongly acid than acid rain.

Primary and secondary acidic aerosols may contribute to visibility impairment before they condense into acid rain or acid fog droplets. In urbanized areas, high levels of fine particles may result in reduced visibility in the form of haze. Under conditions of high humidity, the interaction of the solar radiation with polluted air results in a reduced clarity and affected color of the sky. These two visibility outcomes may vary according to the chemical composition of the aerosol, because different components differently modify the overall refractive index and thus affect how much light is scattered and absorbed. For example, the presence of PM containing sulfate, a derivative of SO_2 under

high-humidity and low-temperature conditions, may result in a yellow haze.

Smog is another by-product of high concentration levels of primary and secondary PM constituted of mineral dust, carbon monoxide and elemental carbon, sulfur dioxide, nitrogen oxides, and organic matter. High concentration levels of either organic matter or black carbon may form into a strongly light-absorbing aerosol that affects the atmospheric radiation field by both scattering and absorption.

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See Also: Air Pollution, Automobiles; Air Pollution/Air Quality; Climate Change, Transportation Impacts From; Environmental Impacts; Greenhouse Gases; Mobile Emissions; Smog; Vehicle Fleet Emissions.

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Partnership for a New Generation of Vehicles

The Partnership for a New Generation of Vehicles (PNGV) was a joint venture between the U.S. government and the U.S. Council for Automotive Research (USCAR), a collaborative research initiative established by the "Big Three" U.S. automakers: DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation. Also known as the Clean Car Initiative, the partnership sought to develop technologies for fuel-efficient, low-emissions vehicles that are safe, affordable, and appealing to the broad consumer market. While the program achieved the majority of its mandate, it fell

short of its final goal of delivering a concept car prototype for production.

In addition to its tangible outcomes related to automotive technologies, the partnership also served as an important early experiment in government–industry collaboration. PNGV’s experiences helped pave the way for future cooperative efforts between federal agencies and U.S. commercial interests in the automotive arena, as well as in other industry sectors.

Formation of the Partnership

USCAR was formed in 1992 in response to increasing globalization in the automotive market, which had resulted in a surge of new competition for U.S. automakers from their counterparts in Europe and Japan. With congressional passage in 1984 of the Cooperative Research Act, which limits the anti-trust liability of joint research and development ventures, the U.S. automakers recognized an opportunity to work together within a technical collaboration to bolster their global positioning.

They created the Automotive Composites Consortium in 1988 to address a need for new structural and semi-structural polymer composites, and soon began working to resolve other issues that involved technologies, such as advanced batteries and vehicle recycling. Four years later, USCAR was formed as a management group to coordinate all the joint research and development efforts among the three automakers.

The Bill Clinton administration brought the federal government into the mix on September 29, 1993, when it established the PNGV as an industry–government partnership under the U.S. Department of Energy (DOE). It was dedicated to amplifying U.S. automotive competitiveness through the collaborative development of technologies that would create a new generation of vehicles featuring significantly enhanced fuel efficiency and reduced carbon dioxide emissions.

The partnership combined the vast research and development resources of the DOE’s National Laboratories and various academic research institutions with the automobile design, production, and marketing capabilities of USCAR and its partners and suppliers. Generally, the U.S. government funded development of long-term, high-risk technologies under PNGV, while USCAR and industry constituents typically funded development of technologies that had nearer-term commercial potential, as well

as provided funds for the adaptation of government technologies to automotive applications and the production of proof-of-concept vehicles.

At PNGV’s request in 1994, the National Research Council created the Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles. The committee conducted annual reviews of PNGV’s research programs, reported on the partnership’s progress to government and industry, and identified potential barriers to PNGV’s success.

Internally, PNGV created several technical teams responsible for specific areas of research and development, such as subsystems, manufacturing, electrical and electronics power-conversion devices, materials and structures, and systems analysis.

Objectives of the Program

PNGV’s key goals were threefold. First, the joint venture sought to appreciably improve productivity and U.S. competitiveness in automotive manufacturing for future generations of vehicles. Toward that end, the partnership targeted research designed to upgrade U.S. manufacturing technology, improve production speed and flexibility, reduce manufacturing costs, decrease environmental impact, and advance overall quality. Second, PNGV targeted implementation of commercially viable innovations to vehicles that could generate better fuel efficiency and fewer emissions than conventional vehicle designs, while maintaining or improving vehicle safety performance.

Research in support of this goal was focused on technologies that reduce the energy requirements of the vehicle’s engine and drivetrain, which is comprised of the parts of an automobile that connect the transmission with the driving axles. The third key goal of the PNGV involved the development of vehicles that could achieve up to three times the fuel efficiency of comparable conventional models while maintaining relatively equivalent cost of ownership.

A steep rise in international oil prices in 2000, matched by climbing gasoline prices in the United States, garnered media attention about the high cost of U.S. driving and the need for fuel economy. The attention strengthened PNGV’s position, but gas prices and fuel efficiency were not major issues that motivated most U.S. drivers at the time. In fact, the early 2000s were the boom years for less-fuel-efficient sport utility vehicles. There was little

enticement for consumers to purchase vehicles featuring higher-cost components and designs merely to improve fuel economy.

That is why it was critically important for PNGV to achieve its goal of developing an affordable vehicle with a fuel economy of up to 80 miles per gallon (mpg) that matched performance, size, utility, and cost of conventional models, while at the same time meeting stringent safety and emissions standards. It was believed that such a vehicle potentially would overcome the lack of economic incentives for consumers and encourage them to purchase a next-generation automobile with greater fuel economy. The contention was that if the partnership achieved its goal and delivered a cost- and attribute-equivalent vehicle, with the added feature of improved fuel efficiency, there would be no reason for buyers to favor conventional models.

The ambitious goal sparked rapid development of vehicle technologies designed to improve fuel economy, including higher-efficiency engines, hybrid drivetrains, and regenerative braking systems.

Achievements

The partnership made substantial progress in its first several years and achieved several significant milestones during that time. By the end of 1997, PNGV reached an important target and succeeded in making technology selections for alternative vehicles based on assessments of system configurations. The group chose the four-stroke compression-ignition direct-injection (CIDI) engine as the most likely option to achieve the stated fuel economy goal in the specified timeframe, although high-efficiency, fuel cell power plants were considered an extremely promising long-range technology option. Once PNGV selected the technology, the joint venture was able to focus its resources on fewer technologies, which would help it define and develop concept cars by 2000, with prototype production slated by 2004.

Employing technologies developed through PNGV in conjunction with their own proprietary technologies, the USCAR automakers each succeeded in developing separate concept vehicle designs by the 2000 target date that, in theory, would generate fuel economies ranging between 70 mpg and 80 mpg.

Chrysler created the ESX-3, Ford developed the Prodigy, and General Motors designed the Precept.

At about the same time, the U.S. Environmental Protection Agency (EPA) released significantly more stringent emission standards for particulate matter and nitrogen oxides compared to those required at the start of the PNGV program. The change called into question the ability of USCAR to meet the emission requirements with the selected CIDI engine in a prototype model by the 2004 deadline.

However, alternative engine options such as homogeneous spark-ignition engines or gasoline-fueled direct-injection engines, which had a better chance of meeting the new emissions standards within the PNGV timeframe, were not as fuel efficient as the CIDI engine. The PNGV participants tried to address the dilemma by reallocating a large portion of the program's resources to projects aimed at resolving the unexpected issues arising from the new federal standards. The efforts were unsuccessful in the end, and none of the Big Three introduced concept car prototypes by the initiative's 2004 deadline.

While the prototype goal was not met, the partnership did generate viable manufacturing and engineering innovations. One such innovation involved the development of a process to convert gasoline to hydrogen for fuel cells. Based on that technology, PNGV transitioned to become the FreedomCAR and Vehicle Technologies Program in 2002, with a new focus on hydrogen and fuel cell research.

Perspectives on the Program

DaimlerChrysler, Ford, and General Motors maintained a manageable, productive partnership with the DOE under the PNGV initiative. The program served as a role model for the approach of its successor, FreedomCAR, and a number of subsequent joint efforts between government and industry.

The core structure of the initiative involved maintaining a few key private partnerships to help reduce complexity. However, having a limited exclusive group of partners can lead to difficulties if there are conflicts of interest among the participants. In the case of PNGV and FreedomCAR, for example, the automakers could potentially be less likely to direct their collaborative research efforts and funding toward technologies that could require stricter standards, costlier production methods, or increased competition.

In terms of funding, the partnership arrangement was inequitable. Federal contributions to the

program ranged from \$100 million to \$200 million annually. In comparison, the combined contribution from the three automakers came to nearly \$1 billion each year. The enticement for the Big Three came in the form of unprecedented access to information, not only about evolving technologies, but also about each other and the inner workings of the government. The sharing spirit broke down toward the end of the partnership as each of the automakers became more guarded about their proprietary information as they neared the production stage for their individual concept vehicles. Outside of the PNGV, the program served to ignite industry interest and pursuit of new more efficient, environmentally friendly automotive technologies.

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See Also: Alternative Fuels; Automobile Design; Emerging Technologies; Environmental Impacts; FreedomCAR and Vehicle Technologies Program; Green Transportation; Hybrid Automobiles/Hybrid Electric Vehicles; Hydrogen Fuel Cells; National Ambient Air Quality Standards; Smart Cars.

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Passenger Van Safety

The Federal Motor Carrier Safety Administration, part of the U.S. Department of Transportation, defines a passenger van as a vehicle carrying 15 or fewer passengers with a varied storage capacity and no restroom facilities. Passenger vans are longer, higher, and wider than smaller passenger vehicles, and they require different driving techniques and strategies. Drivers must rely more heavily on side

mirrors for changing lanes, and they need more road space and additional braking distances. If they are not properly driven and maintained, passenger vans run a higher risk of crashes and rollovers, but if they are properly driven and maintained, the National Highway Traffic Safety Administration (NHTSA) statistics show that vans, defined as minivans and larger, have a lower overall death rate than other passenger vehicles.

Fifteen-passenger vans, originally designed as cargo vans, feature longer bodies and a higher center of gravity, and are less stable and more likely to roll over than smaller vans. Since these vans are used to transport sports teams, church groups, senior citizens, and large groups of people, rollovers and other types of accidents may produce multiple fatalities.

The backs of 15-passenger vans extend 4 to 5.5 feet beyond their rear wheels, so overloading causes instability during emergency situations like turning suddenly to avoid a pedestrian or a vehicle. Sudden turns cause the vans to fishtail, and since they are top and rear heavy, they are predisposed to rollover accidents.

Twelve-passenger vans appear not to have the same rollover problems, and NHTSA research has proven that the rollover risk of 12- and 15-passenger vans escalates significantly when the number of occupants increases from less than five to more than 10. In single-vehicle crashes, vans with 10 or more passengers experienced nearly three times the rollover rate of vans that were lightly loaded. NHTSA reports that inexperienced drivers, improperly sized and inflated tires, and incorrectly loaded cargo and passengers that alter the center of van gravity increase the risk of rollovers.

Fifteen-Passenger Vans

Fifteen-passenger vans are large vans with five rows of seats that are designed to carry up to 15 people, including the driver. They first appeared on the U.S. vehicle market in 1972 as a way for small groups of people to travel together instead of using buses. Many businesses including day care centers, churches, airports, and schools use them. The U.S. Army even bought 15-passenger vans as a matter of economy and convenience.

These 15-passenger vans quickly became popular, with annual registrations increasing from about 150,000 in 1990 to more than 500,000 in 2005. In July

2012, there were about 672,000 registered 15-passenger vans, making up about 0.2 percent of the total vehicle fleet in the United States. The Ford Econo Club E-350, made since 1978, is the most popular model, with 62 percent of registrations. The Ford E-350, the Chevrolet Express 3500, and GMC Savana 3500 are the three most popular passenger vans currently being manufactured in the United States.

Design Issues and Tire Problems

According to the NHTSA, 1,090 people were killed in 15-passenger vans in the United States from 1997 to 2006, with rollover accidents responsible for 63 percent of these fatalities. Many of the crashes involved a large number of passengers from schools, churches, and senior centers because these groups use the vans so widely. The 15-passenger van accidents were highly publicized and prompted research into the design of the vans. The NHTSA reports that the 15-passenger vans have multiple engineering problems, including frequent rollovers. A 15-passenger van has a higher center of gravity, which tends to make it top- and tail-heavy, especially when it carries 10 or more passengers.

A top- and tail-heavy 15-passenger van poses a greater risk for a rollover accident than a smaller vehicle. When a 15-passenger van is fully loaded, it handles differently than when it carries only a few passengers and a light cargo load. Added weight in the back of the van increases the risk of fishtailing and if the van fishtails and causes the driver to lose control and then overcorrect, a rollover accident may happen.

The 15-passenger vans also tend to have tire problems. A simple error like improperly inflated tires can lead to accidents in large vans, because rear tire pressure is different than front tire pressure. Drivers who neglect to check the tire type and pressure that the manufacturer recommends unwittingly create tire imbalances and conditions for a blowout. Underinflated rear tires can overheat, leading to tire failure.

The seating design for large vans, a 2-3-3-4 configuration for a 12-passenger van and a 2-3-3-3-4 scheme for a 15-passenger van, allowing a small passageway along the right side of the van for loading passengers, distributes the weight load more heavily on the left rear tire. If the left rear tire is underinflated, it will generate heat, possibly causing a blowout, a loss of control, and an accident.

Safety Versus Buses

Some organizations purchase 15-passenger vans believing that they are acquiring a cheaper version of a bus, but buses are designed with more safety features, including four rear tires. Van riders often assume they do not need seat belts or shoulder harnesses because most buses do not have them, but the NHTSA states that nearly 80 percent of 15-passenger van fatalities occur because passengers did not use their safety restraints.

Unlike 15-passenger vans, buses often have laminated glass windows and compartmentalized seating, but van passengers not belted in are likely to be thrown through shattered glass during a crash. Fifteen-passenger vans also do not have the interior padding that buses have to protect passengers from being slammed into rigid surfaces. Many buses also have first-aid kits and emergency exits, which save lives in crashes. Buses also have reinforced sides that keep the roof from collapsing in a rollover crash, but when 15-passenger vans roll over, the roof usually collapses all the way to the seats.

Twelve-Passenger Vans

Twelve-passenger vans do not appear to have the same issues as 15-passenger vans, and the NHTSA has issued safety warnings only for 15-passenger vans. The Chevrolet Express/GMC Savana 3500, Ford E-350, and Mercedes Benz Sprinter 2500 are three current models of 12-passenger vans. The NHTSA gives the Express, Savana, and E-350 three stars out of five for rollover resistance and the Sprinter just one star. The experience and skill of the driver is the biggest safety variable. Drivers lacking experience and skill have been major contributors to 15-passenger van accidents.

Safety Advice

Testing has shown that adding dual wheels on either side of 15-passenger vans adds to the vehicle's stability and improves handling in turns and emergencies. A van manufacturer retrofit of the 500,000 vehicles on the highway is estimated to cost about \$300 to \$400 per vehicle or about \$135 in mass-producing new vehicles. In the long term, the vans need to be redesigned to protect passengers in rollover and side impact crashes.

Public Citizen, a nonprofit consumer rights organization based in Washington, D.C., researched, wrote, and published a study titled "Stopping

Rollovers: The Dual Wheel Solution,” asking Ford Motor Company and General Motors Corporation to redesign future 15-passenger vans to diminish rollover propensity, to improve crashworthiness, and to retrofit existing 15-passenger vans with dual rear wheels to reduce rollover susceptibility. Ford and General Motors have not recalled any 15-passenger vans for wheel retrofitting.

According to Public Citizen, the original manufacturer or its dealers should be the only places that refit the 15-passenger vans with dual rear wheels. Aftermarket shops might not realize the complexity and vehicle impact of a dual wheel retrofit and such work would probably require a waiver of their own liability before they would convert any vans. Public Citizen states that since the manufacturers are responsible for the safety hazards on the 15-passenger vans, they should fix the problem and it recommends pressuring the manufacturers to fix the vans. It advises drivers buying new vans not to purchase 15-passenger vans.

Safety Recommendations

The NHTSA and the National Transportation Safety Board state that the ideal solution to the 15-passenger van problem would be retiring and disposing of the van and using a small school bus or other, safer vehicle for transportation. If it is necessary to continue to use the 15-passenger van, these agencies offer some recommendations to lower the risk of rollover and other accidents in 15-passenger vans:

- Screen all drivers of 15-passenger vans. The best course of action is requiring van drivers to secure a commercial driver’s license.
- Remove the rear seat of the vans to reduce loading behind the rear axle.
- Limit the capacity to nine people, including the driver. This dramatically reduces the top-heaviness of the van and the risk of a rollover.
- Load forward seats first.
- Communicate with passengers, parents, and other parties about the high risks of 15-passenger vans.
- Do not tow anything behind the vehicle or load the roof.
- Conduct a full safety inspection of the vehicle, including all tires, before and after the trip. Check the manufacturer’s specifications for tire inflation.
- Include safety items on board, such as a fire extinguisher, first aid kit, and cellular phone for emergencies.
- Require all passengers and the driver to wear proper safety restraints any time the van is in motion.

Federal law prohibits selling or leasing new 12- and 15-passenger vans to transport high school and younger students because of the higher rollover risk. Some colleges, universities, and business organizations have instituted policies against using 12- and 15-passenger vans.

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See Also: Automobile Accident Avoidance Systems; Federal Motor Carrier Safety Administration; National Highway Traffic Safety Administration; National Transportation Safety Board; Vans.

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Pavement Management Systems

Integral to surface transportation is the quality and condition of the surface itself, that is, the pavement used for roadways. Pavement management is the sum of all combined and coordinated activities in design, construction, maintenance, rehabilitation, and resurfacing that are needed to keep road surfaces safe for the modes of transport for which they were installed. From long experience, and with an eye toward protecting this vast, public capital-intensive resource, various industry and government partners have worked together to create and refine a set of policies, functions, and metrics that together are known as pavement management systems. As defined by the American Association of State Highway and Transportation Officials (AASHTO), these systems comprise and facilitate directing all the planning and operational activities “involved in providing and sustaining pavements in a condition acceptable to the traveling public at the least life cycle cost.”

The Greenroads Foundation points to pavement management systems as one subset of asset management systems, which it defines as “a formal systematic process of maintaining, upgrading, and operating a particular asset or network of assets, such as pavements and bridges.” Greenroads also focuses on preservation, which it defines as “a set of maintenance and rehabilitation practices used to improve condition and extend life of a structure(s).”

MAP-21

Highways and roads, whether interstate, state, county, or local, are the critical circulation network of the automotive surface transportation mode. Recognizing this, the executive and legislative branches of the United States have long made focused efforts to promulgate consistent policy, allocate resources, and monitor standards to ensure that this strategic asset is well maintained.

The most recent of these focused efforts came in 2012. In its Moving Ahead for Progress in the 21st Century Act (MAP-21) framework, Congress made federal funds available—a minimum of \$12 million annually—through the Technology and Innovation Deployment Program to accelerate the implementation and deployment of pavement technology in



A team repaves Interstate Highway 84 in Oregon in 2013. The Federal Highway Administration has the authority to compel states to correct substandard pavement conditions, including on their portions of the interstate highway system.

the United States. MAP-21 also updated the power of the Federal Highway Administration (FHWA) to compel states to comply with necessary corrective actions when pavement conditions are substandard—including on their portions of the interstate highway system.

MAP-21 empowered the U.S. Department of Transportation (DOT) to work in conjunction with state DOTs, metropolitan planning organizations, and other stakeholders in the establishment and review of performance measures for pavement conditions. These metrics will vary by geographic region, based on climate, road usage, and other factors. States must document the work they are performing or have plans to remedy situations where pavement has fallen below the codified performance levels.

Survey, Analysis, and Decision

The various state highway planning, engineering, and construction administrators, too, generally

have a solid record of policing their own best practices. These practices, and the principles that underlie them, have been developed hand in hand with private industry in the form of construction companies, material and component manufacturers, and labor unions, and with scientists and academic researchers.

Among the principles that pavement management systems comprise, there is some general agreement on key components. These include (1) manual and digitally enhanced surveys of pavement condition, (2) capture and compiling of the survey statistics in searchable databases, (3) interpretive structured analysis of the data, (4) a set of criteria used for decision making with regard to findings, and (5) practical methods to implement the findings.

Professionals working with pavement management systems have assembled and integrated these principles into working models through the application of an evolving suite of software products that incorporate geographic information systems, relational database interface graphics, decision-making guidance steps, and other modes—all with the goal of making the information clear, readily accessible, and actionable in real-world scenarios.

The information gathered and the decisions that are generated are proposed and ultimately implemented in either a project-level approach or a network-level approach. Considered in another way, these are a choice between bottom-up and top-down. Sometimes at the network level, the finer-grain data with extremely accurate statistics on local conditions is glossed over so that executive decisions can be made system-wide. Such top-down decisions are made with macro-budget priorities in mind. Passing these decisions down the chain to the project level means that project managers must then determine how best to allocate the resources and directives they are given across their timeline and their list of project tasks and local resource availability.

This situational approach to pavement management likely cannot be avoided—and it certainly is not without its own inherent advantages. For one thing, project managers exert some influence on the top-level decisions, as they are responsible for much of the interpretation of project-level data, and they are often called upon to provide much of the context for those decisions. Similarly, due to project managers' familiarity with changing conditions over time in a given locality—road wear, seasonal

fluctuations in traffic composition and flow, etc.—they are typically able to offer expert advice with less available systematized data.

Local-level highway and transportation officials are also by functional position less concerned with macro-level political and economic pressures and influences, which can distract executives from making priority decisions based solely on hard science and hard-won experience. With greater investment in the practical methods and outcomes they know and trust, project-level managers have less reason to be concerned about pleasing outside influencers. They have to please the drivers who use their roads, and their own immediate supervisors. This simplifies their worldview when it comes to interpreting pavement management data and making pavement management decisions.

Practical Metrics

AASHTO, among other bodies, has emphasized the practical refinement of several essential metrics for the analysis of pavement condition by means of periodic surveys. Among the pavement conditions that routinely must be assessed are (1) surface distress, (2) structural capacity, (3) roughness, and (4) surface friction or skid resistance.

Surface distress is the most frequently utilized factor on the part of maintenance crews and supervisors in determining a schedule for and type of remedial action; this type of survey comprises the measurement of observable type, severity, and quantity of distress. Such data is often entered into and forms the basis of a pavement condition index (PCI), which is instrumental in computing rates of deterioration and provides practical timetables for future distress checks and remedial activities.

Structural capacity utilizes nondestructive deflection testing of the pavement as a routine matter to determine load-bearing capacity. This must always be plotted against any and all future or projected traffic increases. In addition, the data from deflection testing often may be augmented by data acquired from core sampling and core component analysis.

Roughness, or ride quality, is generally a function of surface distortion of a pavement segment. From it is derived either a present serviceability index (PSI) or an international roughness index (IRI) reading. These indices are pragmatic measures of what is more broadly considered a perceived, qualitative

metric—the comfort of the ride as experienced by the driving public. However, it can be somewhat reliably converted into a vehicle-operating-cost matrix, and it is an especially important metric on mid- to high-speed roadways.

Surface friction or skid resistance refers to the ability to provide friction—particularly in wet or icy weather—sufficient to reduce or avoid skid-related hazards. This condition metric is especially crucial where vehicular traffic tends to operate at high speeds. A substandard measure of surface friction often will suffice on its own to determine the need for remedial maintenance on a pavement.

Life Cycle and Cost-Benefit Analysis

As decision making proceeds, the practical application phase of pavement management systems takes hold. Here, engineers and policy makers must employ the life cycle view where it affects consideration of the cost-benefit analysis of various outcomes. A decision as simple as whether to repair or replace a segment of pavement can be fraught with unforeseen complications unless the network-level expectations for the materials and finished product are understood from the outset.

In general, pavement management systems are geared toward the lowering of life cycle costs. This result, however, can be reliably attained only by adhering to proper and prudent inspection schedules, performing adequate data analysis, and scheduling the optimal timing of preservation activity.

Applied too early in the life or duty cycle of a pavement surface, remedial efforts will deliver too little benefit to defray the costs involved. Applied too late, the same efforts can deliver sizable benefit—but at a cost magnified many times above the cost for the same effort applied at the correct time in the pavement's life cycle.

Life cycle and cost-benefit analysis algorithms are built into various software packages to complement and assist in the decision-making capacity of pavement management systems' databases. These tools have been included because the measures are so vital to the management mission.

Conclusion

Pavement management systems can help highway authorities and engineers to achieve great savings, as well as to protect the public infrastructure and maintain safety—as long as they are used with

sensitivity to local transportation priorities and in accordance with state and federal mandates. The software and analysis tools will continue to evolve, but it is the professional approach of the planners and administrators, and the combination of their skill sets and experience, that will keep pavement management systems progressing in step with modern surface transportation needs.

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See Also: Bureau of Public Roads; Construction Management; Highway Construction and Maintenance; Information Technologies and Transportation; Interstate Highway System; Road Inventory; State Highway Planning and Finance; Street Design Patterns.

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Pedestrian Malls and Skywalks

Bringing back pedestrians into downtowns is an important goal claimed to contribute to a more vibrant urban center. A good environment for pedestrians would be one where many activities



A skywalk extends from an office building in downtown Tulsa, Oklahoma, in 2008. There were 30 skywalk complexes across North America by 2013, with the largest in Calgary, Canada.

could occur simultaneously without conflict among users, including drivers, cyclists, and pedestrians.

Two of the most common strategies that cities employ to separate pedestrians from vehicles are (1) the development of outdoor pedestrian malls, and (2) pedestrian skywalks. While advancing a similar intent of minimizing the conflict between pedestrians and vehicles, these two strategies have been applied in different contexts. For example, pedestrian malls are typically outdoor, street-level interventions, while skywalks are enclosed and elevated infrastructure. Additionally, each strategy's implementation poses different sets of issues and challenges, as well as distinct benefits and advantages. This entry examines both approaches in terms of their design, accessibility issues, and economic impact and as a congestion mitigation measure.

Downtowns are places of diverse activities and are strengthened by the image of being spaces where people walk. They accommodate a rich mix of uses,

including residential neighborhoods close to offices and retail as well as parks and recreational facilities.

Many downtowns are walkable because they were developed before the car became the primary mode of transport, and newer downtown redevelopment plans are recapturing that feeling by making their cities more pedestrian friendly. In the 19th century, downtown areas allocated almost half of their rights-of-way as walking space. The advent of cars, however, dictated that part of the walkways be converted to vehicle use. Traffic lights were installed to minimize vehicular delay. Vehicles conquered the pedestrian environment, and transportation planners yielded to the demand for space for cars, compromising the convenience and safety of pedestrians.

More recently, due to increasing concern about the environment and greater awareness of the importance of pedestrian-friendly downtowns, "pedestrianization"—defined as the method of transforming areas exclusively for pedestrian use—was introduced. Pedestrianization, considered the most influential driver of the street redesign movement, has changed the public environment of many cities. Two prominent pedestrianization strategies include the pedestrian mall and pedestrian skywalks.

Pedestrian Malls

A pedestrian mall is a street, typically fronted by commercial and retail stores, closed off to all forms of motorized traffic and accessible only on foot. These streets are regenerated to include pedestrian-friendly designs such as new paving, trees, and street furniture (such as park benches and café tables), as well as other amenities that provide visual continuity and special character, and help create an image and a sense of place for the downtown.

The closing of streets to car traffic is said to have originated in western Europe. The aim was to mitigate the escalating problems brought about by urban growth, a denser urban fabric, and increasing car share. Pedestrianization of shopping streets started as early as 1923, just after World War I, when the city of Coventry, in the English midland, was undergoing a downtown redevelopment. But, it was not until the late 1960s that Europe experienced a mushrooming of pedestrian malls. This trend shifted to the United States, which was largely influenced by German models.

One of the pioneer pedestrian malls in the United States is the Kalamazoo Mall designed by Victor Gruen and Associates in 1959 as part of an overall downtown traffic management plan for Kalamazoo, Michigan. By 1970, over 200 pedestrian malls had been implemented in small- and medium-sized U.S. cities.

Pedestrian malls can be categorized as a full mall, semi-mall, or transit mall. A full mall is a street closed to vehicular access that prioritizes pedestrian mobility. It requires physical improvement of the street to make it more pedestrian friendly. In a semi-mall, pedestrian space is expanded, but there is still provision for traffic and parking on a limited basis. Transit malls do not allow private car and truck traffic along the street and, along with pedestrian access, give way to exclusive public transport use. Some of the best examples of transit malls are located in Portland, Oregon; Minneapolis, Minnesota; and Madison, Wisconsin. The experience in European cities has been relatively positive for a number of reasons. These include a higher concentration of residents and workers within the city center, a more diverse mix of economic uses, and better public transport and land use integration.

On the other hand, a number of U.S. cities have experienced a decline in economic activities when pedestrian streets were closed off to vehicular traffic. Those that have succeeded were located in areas with high captive pedestrian markets, including housing areas located downtown, as well as universities, hospitals, and varied amenities (for example, Cornell University in Ithaca, New York).

By 2005, there were fewer than 24 pedestrian malls in the United States because most full malls had been reopened to car traffic once again. Municipalities found that allowing cars was positive for the economy. For example, the opening of Michigan Street in South Bend, Indiana, brought about a 20 percent increase in retail sales, while the opening of Jefferson Street in Burlington, Iowa, has led to a significant decrease in vacancy rates.

Skywalk Systems

A skywalk system is a series of interconnected, elevated pedestrian walkways that link adjacent blocks and buildings while ensuring total separation between pedestrian and vehicle traffic. The elevated walkway joins together a series of bridges right above the street, and second-level corridors

accommodate retail and services, as well as common areas for the public. Generally implemented in cities with cold climates, such as St. Paul, Minnesota, and Calgary, Alberta, Canada, these walkways are climate controlled and appear to simulate the indoor suburban shopping mall experience.

The design of the skywalk system in Des Moines, Iowa, for example, incorporates approximately 36 climate-controlled, glass-enclosed bridges that link 20 downtown blocks. This skywalk system is considered to have developed in an ad hoc manner, but the experience is said to provide a good case study for cities seriously contemplating implementing such a system. Its development is claimed to have increased the variety and vitality of the downtown center, which other cities can learn from and emulate.

The typical reasons for putting in place a skywalk are twofold—to separate pedestrian and vehicular traffic, and to protect pedestrians from the freezing weather. It eventually became clear that skywalks also served as economic catalysts, attracting customers to businesses within the skywalk network. As the network expanded, new developments demanded to be linked to the skywalk system.

The first skywalk system was implemented in Minneapolis, Minnesota, in 1962, and the largest skywalk system in North America has been built in Calgary. However, once skywalks became known as a way to stimulate economic development, they sprang up in some areas with milder climates, including Charlotte, North Carolina; Cincinnati, Ohio; and Dallas and Fort Worth, Texas. The number of skywalk complexes had grown to 30 across North America by 2013.

Compared to car-free pedestrian malls, skywalk systems give separate but equal downtown access to pedestrians and vehicles. The vertical nature of the separation, where pedestrians navigate on the upper level while vehicle circulation is relegated to the street level, may make pedestrians feel safer and more secure as they move around from building to building. Pedestrian malls, because they are at grade, require pedestrians to negotiate heavy volumes of car traffic when they are entering and exiting the pedestrian-only space.

Challenges

As in any development, good design—not only for aesthetics, but also for function—plays an important role in the success, or lack thereof, of

pedestrian malls and skywalks. For example, an ultra-lush landscape design in a pedestrian mall can sometimes impede pedestrian mobility or block views of retail entrances and displays. Portions of skywalks could have lengthy runs of uninteresting, blank walls. Whether above-ground or at ground level, pedestrian areas, like roads, require maps and signs to help people find their way. In a relatively compact pedestrian mall, people may navigate using existing street signs and retail signage. On the other hand, those visual cues may be lacking in skywalks, and signage must be added to keep pedestrians from becoming disoriented.

In contrast to open-air pedestrian and transit malls, elevated skywalks may appear to be private spaces, or perhaps even dangerous, making pedestrians feel uncomfortable in accessing them, especially if some portions of the walkways are closed off during evenings, weekends, or holidays. Access also becomes an issue when there is a lack of proper signage. In the absence of an area map, pedestrians may be uncertain if the skywalks will lead them to their destination, deterring the use of the walkways.

While upper-level skywalks generally accommodate quick-stop, service-oriented businesses that provide for the needs of pedestrians on the go, pedestrian malls tend to hold small, locally owned retail stores and shops designed more for leisure activity. Because of this, both strategies seem to attract different pedestrian groups.

The implementation of skywalk systems is considered to have spurred economic development and successfully encouraged pedestrian activity in city centers, but critics claim they can negatively impact ground-level retail activity, because pedestrian traffic moves to the elevated skywalk.

The presence of pedestrians, who serve as a captive market, is the key determinant of the success of both pedestrian malls and elevated skywalks. Cities and downtowns that lack an adequate captive market to support activities within pedestrian malls or skywalks are sure to fail. However, new groups of people can be drawn into the area, which entails commitment on the part of the city and private businesses to provide special events and entertainment on an ongoing basis.

In short, pedestrian malls and skywalks must be introduced not as an isolated measure but as part of an overall improvement plan for a downtown, complemented by an effective transport management

scheme. Furthermore, its success will also be dependent on the full support of all involved agencies and regular consultation with various businesses and civic groups.

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See Also: Greenways; Pedestrian Travel; Pedestrian-Friendly Design; Street Design/Patterns; Urban Walkways; Walking.

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Pedestrian Safety

Pedestrian safety considers incidents, injuries, and fatalities that occur to people who are walking or using a wheelchair, cane, electric scooter, or other assistive device. According to the U.S. National Highway Traffic Safety Administration (NHTSA), 4,280 pedestrians were killed and 70,000 pedestrians were injured in traffic crashes in the United States in 2010. Pedestrian fatalities accounted for 13 percent of all U.S. traffic deaths, which was comparable to other Western countries. Among developing nations Brazil, China, and Mexico, the percentage was much higher, between 23 percent and 29 percent. In Kenya, however, where a much larger proportion of the population relies on walking to get around, sharing roads with cars, trucks, and the ubiquitous *matatu* (unregulated minibuses), the rate is much higher at 47 percent.

Worldwide, the World Health Organization (WHO) reports that pedestrians make up the following proportions of roadway fatalities:

- Australia (2010): 13 percent
- Germany (2010): 13 percent

- Canada (2009): 14 percent
- United Kingdom (2010): 22 percent
- Brazil (2009): 23 percent
- China (2010): 25 percent
- Mexico (2009): 29 percent
- Kenya (2010): 47 percent

Crash Characteristics

The 2010 NHTSA data show that 73 percent of U.S. pedestrian fatalities were in urban areas, 69 percent involved male victims, 30 percent were between 8 P.M. and midnight, 33 percent involved a pedestrian with a blood alcohol concentration (BAC) of 0.08 or higher, and 14 percent involved a driver with a BAC of 0.08 or higher. People older than age 75 had the highest rate of pedestrian fatalities, but people between the age of 10 and 24 had the highest rate of pedestrian injuries per capita. In general, pedestrian fatalities and injuries are more common in locations, at times of day, and among socioeconomic groups that have more pedestrian activity.

Roadway design is associated with pedestrian safety. Street segments without sidewalks tend to have more fatal pedestrian crashes than segments with sidewalks. Pedestrian crash risk is higher on roadways with faster vehicle speeds, higher motor vehicle volumes, more travel lanes, and longer crossing distances than on narrower, slower streets. Intersections with right-turn channelization islands and signalized intersections that allow “right-turn-on-red” are associated with more pedestrian crashes. Median islands can help mitigate pedestrian crash risk at midblock locations, uncontrolled crossings, and signalized intersections.

Midblock pedestrian crossings with a pedestrian signal, pedestrian hybrid beacon, or rectangular rapid flashing beacon have higher rates of motorists yielding to pedestrians than locations with other types of crossing treatments. In addition, high speed limits and vehicle speeds increase the risk of severe pedestrian injuries. A recent literature review estimated that the chance of the pedestrian being killed is only 5 percent when struck by a vehicle traveling at 25 miles per hour (mph), but the chance of death increases to 15 percent at 35 mph, 40 percent at 45 mph, and 80 percent at 55 mph. Pedestrian injuries tend to be more severe than injuries to automobile occupants.

“Safety in numbers” is the concept that an increase in the number of pedestrians using a roadway

segment, crossing an intersection, or walking in a neighborhood area reduces the risk of each individual pedestrian being injured in a crash, independent of all other changes to the local environment. The causal mechanism behind this concept has not been identified, but researchers have hypothesized that it may be due to drivers being more aware of pedestrians in an area with more pedestrians (leading to more cautious driving), larger numbers of pedestrians reinforcing safe pedestrian behaviors (leading to more careful pedestrian street crossings), pedestrians choosing to walk in locations where pedestrian risk is lower (no behavioral reason), or other reasons.

Safety Evaluation

Pedestrian safety is typically evaluated using police-reported traffic collisions, or crashes. Police crash databases include only crashes that are documented in police reports. Minor pedestrian collisions with motor vehicles, pedestrian crashes in parking lots and on other private property, pedestrian falls, pedestrian collisions with fixed objects, or other pedestrian incidents are rarely captured by police crash reports.

Some of these additional pedestrian incidents can be captured in other sources, such as hospital emergency room records. Since pedestrian crash data are relatively sparse, surrogate measures of behaviors (for example, proportion of pedestrians walking in the roadway, proportion of pedestrians crossing against “Don’t Walk” signals, proportion of motorists speeding), and perceptions of pedestrian crash risk have also been used to evaluate pedestrian safety.

Spatial concentrations of multiple pedestrian incidents, injuries, and fatalities over a relatively short time period (for example, three to five years) are sometimes referred to as “hot spots.” These concentrations may indicate pedestrian safety problems. However, it is also important to recognize that pedestrian crashes tend to occur in locations with the highest pedestrian volumes. Therefore, the actual risk of a crash occurring to an individual pedestrian (expressed as the number of incidents divided by a measure of exposure) may actually be lower in some locations with many crashes than in other locations with few crashes. Example exposure measures include the number of pedestrian crossings at an intersection, pedestrian

crossing distance multiplied by pedestrian crossings, and pedestrian crossing volume multiplied by opposing-direction motor vehicle volume during a particular time period.

Safety Strategies

Common categories of pedestrian safety strategies include engineering, education, and enforcement. Engineering treatments are related to roadway and pedestrian-facility design. These treatments generally provide spatial separation between pedestrians and moving vehicles (for example, sidewalks, shoulders, and buffer space between the street and sidewalk), temporal separation between pedestrians and moving vehicles (for example, pedestrian crossing phases at a traffic signal), or slow-speed interactions between pedestrians and moving vehicles (for example, narrow roadways, raised median islands, chicanes, tight corner radii, curb extensions, raised crosswalks, and flashing beacons that alert drivers so that they can yield to pedestrians at a crosswalk). Roadway and crosswalk lighting enhance pedestrian visibility and safety at night.

Education treatments seek to improve the understanding of pedestrian safety laws and needs among all roadway users. Educational programs are typically offered through schools, state motor vehicle licensing departments, and law enforcement agencies. Safety messages can be shared in classrooms, through neighborhood walks, in print and broadcast media, online, and through social media. These messages are often tailored to specific audiences who have different physical abilities and levels of understanding (for example, elementary school students, college students, new immigrants, young drivers) and tend to target specific behaviors (for example, understanding and obeying pedestrian signals, wearing bright clothing at night, obeying speed limits, yielding to pedestrians at crosswalks).

Enforcement strategies are intended to reduce behaviors that decrease pedestrian safety and encourage behaviors that increase pedestrian safety. For example, targeted enforcement can target pedestrians crossing against traffic signals, drivers speeding, and drivers not yielding to pedestrians in crosswalks. Law enforcement is done by police, but neighborhood groups, parent-teacher organizations, and employers are often important partners in establishing strong enforcement activities. Law enforcement activities are

often combined with educational messages related to pedestrian safety.

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See Also: Complete Streets; Pedestrian Safety, Blind and Elderly; Pedestrian-Friendly Design; Risk Analysis/Assessment; Traffic Calming; Traffic Safety and Risk Assessment.

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Pedestrian Safety, Blind and Elderly

Pedestrian safety is affected by a range of factors related to road design and road-user behavior.

Pedestrians are often referred to as vulnerable road users, borne out by the fact that they comprise over 20 percent of those killed on the roads. There are specific dangers for pedestrians who are blind and/or elderly that are linked to specific behavioral characteristics and design features. These dangers do not always translate directly into heightened risk, detectable in accident statistics, as blind and elderly people often self-regulate their behavior in order to avoid these dangers and mitigate the risk. However, this tends to mean that they suppress their pedestrian activity, and so safety becomes closely linked with issues of access, inclusion, physical activity, well-being, and public health.

Blind and Elderly Pedestrians

The World Health Organization (WHO) estimates that there are 285 million people with a visual impairment throughout the world (approximately 4 percent of the global population). A great deal of diversity exists across this group, in terms of the severity of visual impairment (for example, 39 million are totally blind, approximately 0.5 percent of the global population), and in terms of the impact their impairment has on their daily activities. Visual impairment is known to be strongly associated with aging. For example, approximately 65 percent of visually impaired people are over the age of 65, and among those over age 50 the prevalence of visual impairment is thought to be between 10 and 20 percent.

Statistics on pedestrian accident risk specifically relating to blind and elderly people are not widely collected. Where statistics disaggregated by age group do exist, the picture is different in different countries. However, it is interesting to note that in the United States, the age group with the highest risk of being killed as a pedestrian was that over 75 years of age.

One of the key ways in which visual impairment impacts people is the way it affects them getting about as a pedestrian. In the largest recent survey of visually impaired people, “mobility on foot” was by far the most frequently reported travel difficulty among respondents. Particular problems cited by respondents to this survey included a lack of confidence in going out alone or to unfamiliar places, obstacles in the environment that made navigation more difficult, and fears about busy traffic. More generally, it is widely acknowledged that reduced walking speed

and slower reaction time among elderly people are particular risk factors, while the likely severity of an accident involving an elderly pedestrian will be increased due to age-related physical frailty. Consequently, for many visually impaired and elderly people, fear of getting around means they do not go out as much and/or that they spend more on taxis as a means of overcoming the need for mobility on foot. This leads to suppressed levels of physical activity (with consequent negative impacts on health and well-being) and reduced levels of disposable income, among a group often already experiencing lower than average levels of personal income.

Visually impaired people’s lack of confidence about going out alone or in unfamiliar places results in large part from difficulties with orientation and wayfinding, and the likelihood of becoming disoriented and unknowingly putting themselves in situations of heightened danger. When thinking about this, it is important to acknowledge the diversity among visually impaired people and the variation this leads to in individuals’ coping strategies. For example, researcher Ross Atkin found it informative to group visually impaired people into (1) those who rely on their residual vision, (2) those who use a guiding cane, and (3) those who use a guide dog.

The challenge that emerges is to develop an “environmental information system” accessible to all. Scholar Romedi Passini expresses this as “a coherent ensemble of architectural and graphic cues that provides the decision-making user with adequate wayfinding information at the appropriate place in a form that is both accessible and understandable.” The challenge then for design is how to put together this coherent ensemble of architectural and graphic cues to draw meaningfully on these information channels.

Unfortunately, a lot of the research in this area is old or reliant on small samples. It seems clear that better understanding is needed of what spatial information should be given; in what form that information should be given; at what locations information should be given; and how these vary with key parameters, for example, visual impairment and time and how they relate to various technologies.

Design and Planning Principles

It is well known that risk to pedestrians is increased when road design and land use planning

do not appropriately incorporate the pedestrian by including, for example, delineated footways, controlled crossing points, or adequate lighting. With specific reference to visual impairment, The United Kingdom's (UK) "Guidance on the Use of Tactile Paving Surfaces" sets out five more key design principles:

- Layouts of all pedestrian areas should be simple, logical, and consistent.
- Contrasts in color and tone should be used to accentuate the presence of certain key features.
- Orientation and wayfinding information should be provided by the use of high-visibility and, where appropriate, tactile signing.
- Lighting levels should be even and adequate and should minimize glare.
- Important information about the environment should be conveyed by the use of nonvisual features.

UK industrial designer Ross Atkin, in his findings for a report prepared for the UK Commission for Architecture and the Built Environment (CABE), divides a number of design features into several categories. The first category includes features that benefit all visually impaired people:

- Predictability
- Smooth, even paving, and streets free of obstructions
- Pedestrian-triggered signaled controlled crossings with audible or tactile indicators

Features relevant to those with residual vision include the following:

- Clear tonal contrast (for example, between footway and carriageway, or between street furniture and the surrounding paving)
- Colored paving
- Level surfaces
- Wide footways

Features relevant to visually impaired long-cane users include the following:

- Footways that are not too wide



A wide strip of blister-surface tactile paving alerts visually impaired pedestrians to the beginning of a street crossing in Evanston, Illinois. The use of tactile paving as a warning surface is an increasingly common addition to street surfacing.

- Well-defined curbs
- Tactile paving to alert to the presence of a pedestrian-crossing point or to delineate footways from carriageways where there is not a well-defined curb
- Unobstructed building lines
- Guidance paving in pedestrianized areas and around bus stops or other obstructions
- Guard rails

Features relevant to guide dog users include the following:

- Wide footways
- Well-defined curbs
- Tactile paving to alert to the presence of a pedestrian crossing point or to delineate footways from carriageways where there is not a well-defined curb
- The sound of traffic

Issues of pavement width and the presence or lack of well-defined curbs and tactile paving are points where one group's preferences would appear to be at odds with others. The challenge then is to find ways to resolve these conflicts, and this links to the process of inclusive design. CABE set out five key principles of inclusive design:

1. Place people at the heart of the design process.
2. Offer choice where a single design solution cannot accommodate all users.
3. Avoid steps.
4. Ensure that doors are highly visible and, wherever possible, open automatically.
5. Make space for everyone.

In particular, "placing people at the heart of the design process" means that the process should be one that involves users and, by doing so, seeks to achieve an outcome that includes the widest range of users possible. One crucial aspect of this is the stage at which the blind and elderly community is involved in the process. The danger is that this occurs too late in the process, at which point any case for making changes could be viewed as obstructive and/or to be too substantial to incorporate at that stage.

Tactile Paving

Since its first use in Japan in the late 1960s, tactile paving for the purposes of either hazard avoidance and/or guiding has become increasingly more widespread in its application. It has become commonplace in the UK. The UK "Guidance" sets out seven types, including both warning and amenity surfaces.

The five types of warning surfaces are blister surface (which incorporates flat, round protrusions) for pedestrian crossing points, corduroy hazard warning surface, platform edge (off-street) warning surface, platform edge (on-street) warning surface, and segregated shared cycle track/footway surface and central delineator strip. Amenity surfaces include guidance path surface and information surface.

Whether and how the possibility of seven types of tactile paving can be reconciled with the principle of keeping pedestrian environments simple, logical, and consistent is a contentious point. There

is a view that the multiple types of possible surface lead to confusion among designers and users alike.

Confusion among those implementing the different surfaces has led to inconsistent application, which further accentuates the confusion among users. Hence, amid the moves to develop an international standard there are calls for some simplification.

Shared Space and Shared Surfaces

"Shared space" is an approach to designing streets based on removing the demarcations between pedestrian space and road-user space, on the basis that if the street space is shared, this will naturally lead to greater freedom for the pedestrian and greater caution on the part of motorists. Initiated in the Netherlands, it is beginning to be adopted elsewhere as a means of revitalizing town center areas.

However, it involves some controversy regarding its impacts on pedestrian safety, particularly for visually impaired people, elderly people, and children. In particular, visual impairment advocacy organizations, such as the Guide Dogs for the Blind Association in the UK, strenuously make the case that visually impaired people rely on traditional street design and demarcation in order to keep themselves safe and to orient themselves, and that to remove these aspects leads to increased danger, reduced confidence, and suppressed travel.

Behavior

Driver and pedestrian behavior can also be an important influence on pedestrian safety. Easter Seals Project Action provides simple and useful guidance on behavior intended to promote increased pedestrian safety and access. Its tips for drivers and pedestrians include the following:

- Drivers should be aware that some people might not be able to see your car or move quickly.
- Drivers should be aware of people with service animals and white canes.
- Drivers should be aware that pedestrians and cyclists cannot hear electric or hybrid cars. Be especially careful in parking lots and when backing up.
- Drivers should be aware that loud noises, such as car radios, can impair the

navigation of people using auditory cues for street crossings.

- Pedestrians should wear reflectors and light-colored clothing; small lights and reflective straps are inexpensive and can be found at local bike stores.
- Pedestrians should plan their route and consider all options to travel safely. Traffic and lighting may vary by time of day. The shortest route may not be the safest.

It also warns against driver and pedestrian distraction, be that visual, manual, or cognitive distraction. Given that texting requires visual, manual, and cognitive attention, it strongly warns against texting while driving or walking and, more generally, cautions against use of a mobile phone while driving or walking.

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See Also: Accessibility and Mobility; Elderly and Disabled Travelers; Handicapped Access; Pedestrian Safety; Pedestrian-Friendly Design.

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Pedestrian Travel

The generally understood definition of a pedestrian is anyone who walks. And, while pedestrians are everywhere, especially in urban settings, they are often seen not as a major part of the transportation network but as something apart and sometimes even a nuisance.

Pedestrians are, however, an integral part of the intermodal system of transportation. They are not a peripheral entity but are tied very closely to other modes of transportation. Pedestrians affect the planning process that results in the creation and maintenance of transportation infrastructures. The presence of pedestrians affects the movement of people and goods and has significant economic effects.

In 1991, the U.S. government recognized the importance of pedestrians with the passage and signing into law of the Intermodal Surface Transportation Efficiency Act of 1991. Known as ISTEA, this law defined how planning to meet transportation requirements through the use of intermodal means would be done. A key part of this intermodal perspective was the recognition that people walking, especially when that walking is between other transportation points, constitutes an important segment of transportation in the United States.

As might be expected—because government funding, planning, and work on the transportation infrastructure were involved—a legal definition was developed to define what constituted a pedestrian. States (which were also part of planning and implementation processes for ISTEA-related initiatives) and the federal government created those definitions.

In Minnesota, a pedestrian is anyone on foot or in a wheelchair. Ohio's definition reads that a pedestrian is "any natural person, afoot." California's definition include not only people on foot but also anyone operating any human-powered vehicle that is not a bicycle; self-propelled wheelchairs are also covered under this definition. The definition found in Title 23 of the U.S. Code states that any person traveling on foot, as well as any mobility-impaired person using a wheelchair, is a pedestrian.

Pedestrians and the Transportation System

An individual living several miles outside a major city might drive directly to that city to go to work. After reaching their destination, they will park the car and walk to the office. That simple act

of walking has been part of the solution to their transportation problem of how to get to work. Sidewalks or other means of access and infrastructure are needed to be sure people can walk from the parking area to their jobs.

In other instances, walking takes on a more significant and complex role. If people work in an area where there is a public transportation network, their participation as users of transportation infrastructure expands their role. For example, they may drive their cars to a commuter rail station, walk to the station after parking their car, walk from the commuter-rail destination directly to their work destination or to a bus or subway station. Then, they will walk from there to their place of work.

In this expanded scenario, people are using more pedestrian-centered infrastructure, which includes not only sidewalks but also such structures as elevated walkways, transfer stations, and pedestrian areas near train stations, as well as shopping malls and, perhaps, sport venues. In some locations, the use of pedestrian-oriented infrastructure is more intense than in others. In New York City, for instance, it is estimated that less than half of all households have a car. That means that more than half of the population walks as one of their primary means of travel.

Studies of pedestrians and their behavior as a means to support transport planning take on a very high degree of urgency in the current environment and provide a compelling argument for the importance of the research and the subsequent allocation of funds to support it.

Another factor that makes pedestrian behavior and its study so important is the element of safety, which has both economic and societal ramifications. According to the National Highway Traffic Safety Administration (NHTSA), approximately 175,000 pedestrians were killed in motor vehicle crashes between 1975 and 2001. Although the long-term trend has been reduction in pedestrian deaths, they still represent losses in life (affecting society) and have an economic effect in lost productivity, medical bills, and lost wages.

One other factor (potentially significant politically) that bears on the interest in studies of pedestrian behavior is the presence of pedestrian advocacy groups, which are organized to ensure that safe and efficient pedestrian access is incorporated into any new developments, as well as to fight for

restrictions on vehicular traffic that they see as infringing on pedestrian rights.

Finally, a consideration that affects pedestrian behavior, and consequently infrastructure planning and funding, is the special consideration that must be given to guarantee access to disabled pedestrians. Consideration of this segment of the population is not a matter of choice for U.S. governments at any level; the Americans with Disabilities Act (ADA) of 1991 guaranteed that disabled persons would have access to (among other things) the same transportation opportunities afforded to the rest of the population. The Justice Department, often pushed by advocacy groups, has initiated lawsuits in every state to resolve transportation barriers. The city of Sacramento, California, for example, was required spend 20 percent of its annual transportation budget to bring its facilities up to the standards mandated by the ADA.

The act of walking is not simply an individual act, because, for example, if a pedestrian does not get to work, it will have an economic effect on them personally and the society at large. If there is no or inadequate infrastructure that supports pedestrians getting to work, there are adverse economic consequences for companies and the cities in which they are located. The infrastructure support for pedestrian traffic requires a substantial investment, which, in turn, requires intelligent and informed planning. That planning is best carried out with an understanding of the characteristics of pedestrian behavior.

Elements of Pedestrian Behavior

Pedestrian behavior, ideally, should have a major influence in the design of any venue where people will walk, including sidewalks, elevated walkways, pedestrian areas in train or bus stations, airports, malls and shopping centers, and any place where people will gather. In order to effectively research and provide accurate qualitative and quantitative information, however, researchers must first identify and understand the characteristics of pedestrian behavior.

Some analysts have compared pedestrian flow to fluid mechanics, noting the similarities between the flow of people and water, as well as how both can be influenced by obstacles. Based on fluid mechanics, planners learned that creating a zig-zag pattern or using columns in a pedestrian area can break up congestion.



Pedestrians use a crosswalk over double-decker tram rails on a Hong Kong street in 2008. There is a growing awareness that pedestrians are an integral part of the intermodal system of transportation and are closely tied to other modes of travel.

Other analysts note that such an analogy is too simple-minded, especially when considering that potential emotional (for example, panic) factors also come into play with humans that would never apply to water. To one degree or another, however, most agree that physical configuration does play a major role in influencing pedestrian behavior.

There are other factors, however, that affect pedestrian behavior. These include some general, but also sometimes personal elements. The size, health, weight, walking speed of the pedestrian, following distance behind others, and the number of other pedestrians are among the influencing factors.

The reason for the pedestrian's trip affects behavior. Generally, analysts have divided the reasons into three categories. The first is that the trip is required by necessary activities such as work or errands. Second, there are optional activities that take place as opportunity affords, such as going out for a walk on

a nice day. Finally, there are trips to and from social activities that are conducted in public places with other people.

Even the emotional state of the pedestrian (for example, after a win or loss at a sporting event) is relevant. The physical environment in which the pedestrians are walking will also have an effect. Thus, empirical evidence from previous design decisions at other venues will influence design and construction choices later on.

Another aspect of behavior is that influenced by social cues, such as pedestrians deferring to and giving more space to female or elderly pedestrians when they encounter them, even in a crowded situation.

Research on Pedestrian Behavior

While a great deal of pedestrian research has been conducted (with a vast increase since ISTEIA and its successor bills were passed), the discipline is still in an early stage of development and evolution. Until fairly recently, research has taken what is referred to as a microscopic rather than macroscopic view. In other words, earlier studies (and many in progress now) examine the choices of speed and other factors made by individuals.

What researchers are now studying more intensely—falling into the macroscopic category—is the effect groups of pedestrians have. They are studying what influences groups, whether they are people who know one another or simply a cohort group that has spontaneously formed.

How the group shapes itself (into either a convex or concave formation), how much space it has between members, and how that group navigates clear spaces and bottlenecks are coming under increasing study. In any event, there is validity in both approaches, whether the individual is studied as part of a larger transportation flow (macro) or as an individual agent who may affect the larger flow (micro).

Whether individuals or groups are studied, there are several considerations that must inform the study if it is to be successful. Among these are a picture of the personal characteristics of pedestrians, time of day, reasons for the trip, properties of the infrastructure being used, and environmental considerations such as the weather and season.

The immediate circumstances in the pedestrian area are also significant. Planning for many baby

strollers on a Sunday afternoon will be different from preparing for masses of rush-hour walkers. In the event of an emergency (that is, panic situations), the dynamic will again be altogether different.

The methodology for studying and analyzing pedestrian behavior is usually mixed, and there is a great deal of literature in the academic journals concerning new methods to more accurately measure and predict pedestrian behavior. Observation of some sort is essential, many times taking the form of videotaping a pedestrian area. Software to support analysis based on observations of trends and patterns, as well as simulation software, is increasingly used.

There is also a growing awareness that an important element in research is an ethnographic component. Cultural differences in when people go to work and return home, the speed with which people walk, the amount of space that they maintain between themselves and others, and their tendency (or not) to stop on the way home are all factors that are increasingly being considered. Researchers understand that the differences between pedestrian behaviors in Hong Kong, London, Warsaw, or Boston are potentially major factors to be considered as part of transport planning.

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See Also: American with Disabilities Act of 1990; Handicapped Access; Pedestrian Malls and Skywalks; Pedestrian Safety; Pedestrian Safety, Blind and Elderly; Pedestrian-Friendly Design; Walking.

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Pedestrian-Friendly Design

Walking is more than simply a utilitarian function. It, in fact, characterizes the very essence of human life. Walking offers various economic, environmental, physical, and social benefits at various scales. At the regional level, it plays a critical role in multimodal transportation systems by linking various modes of transport. At the neighborhood level, it contributes to the quality and vibrancy of community life. At the individual level, it contributes to increased cardiovascular fitness, reduced stress, stronger bones, and mental alertness. Also, walking contributes to inclusive mobility, as it is considered a more equitable mode as most everyone can walk (including those below driving age), while not everyone can drive.

However, the levels of walking, and the potential for making important trips by foot or in combination with other modes, have dwindled and are further threatened by the increasing levels of motorization. In communities where vehicles have become the priority over pedestrians, streets are perceived to be unsafe for walking. But with renewed efforts toward developing more sustainable and safer communities, alternative approaches such as improving the built environment to be more pedestrian friendly are one key strategy to encourage more walking. Pedestrian-friendly design helps enhance the built environment. It is also an effective way to encourage walking, attract more pedestrians, and promote higher levels of pedestrian travel.

Pedestrian-friendly design of streets contributes to the economic vitality of cities. Recent research has shown that well-designed and maintained pedestrian facilities and pedestrian-friendly streetscape improvements have increased retail sales in urban centers. More specifically, a study in Toronto has shown a decrease in vacancy rates while bolstering property values when pedestrian-friendly features were introduced. Moreover,

people who live in neighborhoods with higher levels of density, a mixture of land uses, access to public transit, and pedestrian-friendly features tend to use their private car less than residents in neighborhoods that lack these attributes. Enhancing pedestrian-friendliness in neighborhoods is a positive planning factor that provides multiple benefits.

Empirical evidence is not yet complete but a number of studies have consistently found a strong relationship between the characteristics of the built environment and levels of walking. As an example, a study that looked at the effects of site design on pedestrian travel in mixed-use medium-density environments found that locations that provided facilities and direct routes for pedestrians resulted in higher incidence of walking. Similarly, a University of Washington study confirmed that site design and community layout, as well as the presence of well-designed and maintained pedestrian facilities, are elements that can potentially predict pedestrian volumes in suburban locations.

While evidence suggests that the availability of pedestrian facilities encourages walking and attracts more pedestrians, it is also true that when pedestrian access is expanded and existing conditions for pedestrians are significantly improved, through the inclusion of pedestrian-friendly design, higher numbers of pedestrians can be expected to use the system not only to undertake necessary activities but what Jan Gehl categorizes as desirable and social activities, thereby promoting higher levels of pedestrian traffic and activities.

Design Features

Pedestrian-friendly design is a built environment-related strategy that assists in enhancing the physical environment and increasing the amount of physical activities, including walking. In this regard, the planning and design profession is in an important position to better understand and cater to the improvement of the pedestrian environment and encourage active travel. Pedestrian-friendly design is a key tenet in urban design and planning for compact cities, smart growth, transit-oriented developments, and new urbanism. For example, the “new urbanism” movement, a group comprised of proponents who advocate walkable neighborhoods, proposed the following elements as contributory to a more pedestrian-friendly environment: mixed-use

streetscapes with corner shops, the provision of diverse housing types that incorporate neotraditional neighborhood design, and design that ensures proximity to public transit. These elements, they claim, enhance mobility of residents and provide an environment that is safe for walking. In addition, pedestrian-friendly design considers pedestrians to be the most important entity when planning for transport. This is further espoused by what scholar Todd Litman connotes as the “green transportation hierarchy.” This concept proposes that pedestrians must be at the top of the road user hierarchy, implying that pedestrians are the most important entity in planning for streets.

Reid Ewing, author of *Pedestrian and Transit-Oriented Design*, a joint publication of the American Planning Association and the Urban Land Institute, suggests 28 pedestrian-friendly design features that can be categorized into three groups. These include (1) essential features perceived to be critical to the success of pedestrian-friendly sites; (2) highly desirable, though not mandatory, features that contribute to bettering the pedestrian environment; and (3) nice additions, not essential but worthwhile having within pedestrian-oriented locations. Essential features include medium-to-high densities, a mix of land uses, short-to-medium-length blocks, regularly spaced transit routes, two- or four-lane streets, continuous sidewalks wide enough for couples, safe crossings, appropriate buffering from traffic, street-orientated structures, and comfortable and safe places to wait.

Density is seen to be a critical feature to support pedestrian-oriented environments. Density, specifically residential density, is seen as an important and critical predictor of nonmotorized travel. A sufficient density and concentration of people can support a variety of activities colocated within a relatively small zone, which can then be accessed by walking. High densities are achievable in communities by promoting small-scale buildings with high lot coverage.

A mix of land uses that accommodates pedestrian-supportive land use patterns is also a plausible and practical strategy to increase density, attract pedestrians, and support pedestrian activities. One example is the combination of complementary functions such as commercial and retail with residential. There are, however, certain land use patterns that are unsuited to walking, such as poor access design

to and within developments, better access to cars than public transport, and inconvenient or unpleasant pedestrian facilities.

Pedestrian safety is also one of the major concerns when designing for pedestrian friendliness. For example, by providing safe crossings and safe places to wait, pedestrians' perception of walking as being risky is minimized.

A complete system of interconnected streets, pedestrian walkways, and other pedestrian facilities provides a continuous and seamless walking path between origin and destination, ensuring good pedestrian circulation and access, especially to highly used origins and destinations. Compact and well-connected land uses are related to lower vehicle miles traveled (VMTs) and lower emissions of ozone precursors.

Pedestrian-oriented schemes such as creating active frontages to local area retail and commercial venues are important strategies that encourage pedestrian presence, serve as a territorial passive surveillance approach, and thereby contribute to an overall better pedestrian experience.

Ewing mentions a number of highly desirable features: commercial land uses, grid street network, traffic calming along access routes, closely spaced shade trees, minimal dead spaces, parks and public common spaces, small-scale structures, and pedestrian transit facilities. While not mandatory, he also mentions "nice" attributes to include: streetwalls, functional street furniture, coherent signage, special pavement, and public art.

Risks and Benefits

While proponents of a pedestrian-friendly environment have continually stressed its positive values, some authors have also pointed out its associated risks. As an example, the increased levels of outdoor physical activities may also be detrimental to one's health given the increased exposure to air pollution and traffic hazards. It is, therefore, crucial to combine expected lower vehicle miles traveled with a significant shift to nonmotorized modes of travel to significantly counteract the potential for increased exposure to associated environmental risks.

Whether pedestrian friendliness of the built environment influences walking or an individual's preference for active travel impacts their choice of a residential location, the need to enhance the quality of place by introducing pedestrian-friendly

features helps support higher pedestrian patronage. It has been documented that a well-designed physical environment continues to influence residents' physical activities. Thus, people should be more physically active and more likely to use active transport modes such as walking in an environmental context that offers continuous and well-maintained walkways, a gridded street network, well-lighted paths, greater safety, proximity to destinations, and an attractive walking environment.

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See Also: Livable Streets; Neotraditional Neighborhoods and Transportation Impacts; Pedestrian Safety; Pedestrian Travel; Street Design/Patterns.

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People Movers

People movers are a type of automated transit system that transport passengers via driverless vehicles along fixed routes. They may be implemented for purposes as simple as transporting passengers along short routes such as from terminal to terminal in airports (and the motorized walkways used in some airports are essentially the simplest version of such systems) to intracity and intercity transit. Because the drivers' salaries and benefits are the largest part of the operating cost of a rapid transit system, automated systems are ideal for implementations such as free transit service (such as in airports or some

cities) and transit in areas that cannot afford greater operating costs.

Most people mover systems use automated guideway systems that employ a guide such as a rail or other system in order to both provide physical support for the vehicles and direct the vehicles along their route. Like most conventional guideway transit systems (subways, trains, and streetcars), they are grade separated, meaning that they are separated by height from other transit routes so as to not interfere with traffic flow. In confined areas such as airports this is accomplished easily by building a rapid transit system route that skirts the perimeter of the passenger-accessible areas without cutting off pedestrian traffic flow. In other areas, more planning is required.

History

The earliest significant automated rapid transit system was built for the 1924 British Empire Exhibition, a globally touring exhibition of British culture and technology meant to stimulate trade between the British and the 58 countries of their empire. On the London stop of the tour, the “Never-Stop Railway” was constructed to bring passengers to various parts of the exhibition. It deployed 88 driverless carriages on a continuous track on parallel concrete beams, with pulleys guiding the carriages. A revolving screw thread propelled the carriages and adjusted the speed in order to slow carriages down as they approached disembarkment stations. The railway ran for two years.

Automated systems that service airports, commercial districts, and theme parks are often called people movers, a term originally applied in the 1960s to such systems developed by Goodyear and the Expo 67. The term reflects the purpose of the system rather than its design, which may be based on cable traction, linear motors, or conventional electric motors. Smaller systems are usually categorized by themselves, as personal rapid transit systems (PRTs). Intense development of automated rapid transit systems began in the 1960s amid growing concerns about urban congestion, population growth, the pollutive effects of car ownership, and the effects of suburban sprawl. Numerous concerns, ranging from the environmental (seeking to limit emissions by encouraging development of public and mass transportation) to the commercial (making tourist areas and shopping districts more easily accessible), motivated

development throughout the world. Though subway systems continued to be expanded in urban areas, much of the people mover development focused on using elevated tracks, which were cheaper to deploy and faster to construct. These automated people mover systems had numerous appeals, including reduced operating costs and the practicality of fixed routes, to urban planners.

Mid-1960s legislation led to the funding of federally developed automated transit systems under the 1966 Downtown People Mover Program. Ford Motors, Otis Elevator, aerospace company Rohr (now Goodrich Aerostructures), and aerospace firm Ling-Temco-Vought all developed systems in the next few years and exhibited prototypes in the early 1970s. Like many initiatives born in the early 1960s and 1970s, though, enthusiasm and support soon waned, and like many advances in transportation, they saw little development in the 1980s.

Operating People Mover Systems

One of the few automated transit systems successfully developed in the Downtown People Mover Program was the Metromover, which began operations in Miami, Florida, in 1986, 20 years after the program’s creation. The Metromover expanded its route coverage in 1994 and now offers free transportation to 32,000 riders a day, connecting downtown Miami and the neighborhoods of Brickell, Park West, and Omni. The Metromover serves 21 stations, each about two blocks apart, and can bring passengers within a short distance of any building downtown. It is integrated with the paid Metrorail system through two stations, at Brickell and Government Center. The Metromover is today one of only three people movers used for downtown public transit in the United States, and it is the most comprehensive of the three. It set a daily ridership record for people movers in 1987, just after finishing its first year of service, and has been free since 2002 (when it was discovered that the cost of collecting fares exceeded the revenue generated). The operating cost averages roughly \$1.02 per ride, based on fiscal year 2007 figures, but the economic benefits to the Miami community are believed to be substantially greater.

The vehicles used by the Metromover are a combination of Adtranz C-100s and Bombardier Innovia APM 100s, both of which are developed by the company now known as Bombardier Transportation

(formerly Westinghouse Transportation Services, AEG Transportation, and Adtranz). The C-100 was first deployed at Tampa International Airport in 1971, and most C-100s today are used for intra-airport transit, as are most CX-100s, the official model replacement for the now-deprecated C-100 design. Airports using either C-100s or CX-100s include most of Florida's major airports, London Gatwick Airport, Hartsfield-Jackson Atlanta International Airport, and Seattle-Tacoma International Airport. The Innovia APM 100 is also based on the C-100 designs and debuted at Dallas-Fort Worth International Airport in 2005.

The other successful system developed under the Downtown People Mover Program is the Detroit People Mover (DPM), the developers of which persisted despite cuts to funding in the 1980s and a scaling back of original goals and intentions. It began service in 1987, shortly after Miami, and continues to operate. It may be deemed less successful than the Metromover by most measures, serving primarily out-of-towners, with operating costs half again as high as the Metromover's, despite a much lower ridership (7,500 riders a day in fiscal year 2008). The DPM serves 13 stations in a loop, using 12 ICTS Mark I cars made by Bombardier.

The only downtown people mover program in the United States that did not originate with the 1966 People Mover program is Florida's Jacksonville Skyway. An automated monorail serving eight stations, the Skyway has been extended three times since beginning service in 1989 with three stations. Currently, it operates two routes, with a daily ridership of about 1,300. It has been widely criticized for attracting a lower ridership than projected, even after route extensions intended to increase usage.

Urban people movers are somewhat more successful outside the United States. Vancouver's SkyTrain system in Canada is the largest automated transit system serving a metropolitan area. It consists of 42.7 miles of grade-separated track, primarily on elevated guideways, divided into three operating lines with a fourth under construction. The SkyTrain began operation in 1985 and today includes 47 stations, with a daily ridership of 396,500—more than the combined ridership of all downtown-serving automated transit systems in the United States—and close to the annual ridership of Jacksonville's system. Its operating fleet consists of 298 cars, which travel between 40 and 55 miles per hour. It is operated by



The Detroit People Mover (DPM) at Times Square Station, one of the system's 13 stations, which are connected in a loop. In 2008, the DPM had a ridership of 7,500 riders a day making use of 12 ICTS Mark I cars manufactured by Bombardier.

several companies under contract with TransLink, the regional Canadian transportation agency, and shares a fare system with other transit services in the region, allowing passengers to pass back and forth through different services for the sake of route flexibility. The 2008 operating costs were \$83 million, but advertising alone brought in \$360 million in revenue, with additional revenue provided by a transportation fund drawing on fuel and property taxes. The SkyTrain has had a considerable effect on the development of metropolitan Vancouver in the last 25 years, with over \$5 billion in private money invested in developing areas within a short walk of SkyTrain stations, and the population of the service area rising from 400,000 when the service began to 1.3 million in the most recent census, a threefold increase.

Outside of such downtown areas, automated rapid transit systems are common in theme parks, international airports, and large hospitals. But one of the most important types of implementation has been the adoption of automated rapid transit in smaller cities that have trouble sustaining the

operating costs of a transit system. Many smaller French cities, for instance, have adopted automated metro systems, as have the Italian city of Perugia and a number of Asian cities.

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See Also: Automated Guideway Transit; Automated Transit Systems; Personal Rapid Transit.

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Personal Rapid Transit

Personal rapid transit (PRT) systems are a subset of automated guideway transit (AGT) systems, at the smallest end of the capacity spectrum. Recent plans for PRT systems have sometimes used the terms *podcar* or *pod*. While typical people movers, another form of automated transit system, are often similar in capacity to traditional buses or train cars, PRT systems transport either individuals or small groups of up to six people. The vehicles are considerably smaller than those used on other automated transit systems, no more than 20 feet long and 8 feet wide, with a maximum travel speed of 20 miles per hour. Typically, PRT systems are used for direct routes from one point to the other, with no stops along the way. PRT systems are sometimes compared to automated taxis, but because they follow a guideway, they lack the flexibility of an automobile.

PRT systems are driverless, traveling along an aerial or underground guideway system. Because payroll is the biggest annual expense in transit

systems, automated systems reduce costs of transit and make it financially feasible to offer free transit in certain situations. For instance, automated systems are used in many airports, which assists in airport layout by reducing the time it takes for passengers to arrive at a given terminal. However, because they carry only a few passengers at a time, PRTs can offer more flexible types of service.

After years of attempts at developing PRT systems, most of which were failures, the Advanced Transit Association (ATA) in 1988 created a set of guidelines defining what is meant by PRT, as opposed to other transit systems. PRT systems are fully automated and operate on a dedicated guideway, either underground, at ground level, or aboveground. They are small vehicles available 24 hours a day for one to six passengers. A PRT vehicle is able to access all the guideways and stations on a fully coupled network. Service is direct, without transfers or stops. Service is available on demand. Ideally, a PRT system offers the same access to the elderly and disabled as other transit systems do; though this is not specified in the ATA guidelines, it can be inferred from the Americans with Disabilities Act.

PRTs were one of the many transportation concepts that developed in the tech and engineering boom that followed World War II, in part as a result of the amount of resources and attention devoted to training engineers in the war years and subsequently in the Cold War, and in part because of the baby boom, a subsequent housing boom, and the changing layout of the country. The federal government began funding studies to develop automated transit systems, including PRTs, in the 1960s, and in the 1970s numerous transit possibilities competed for attention, funding, and planning committee preference, including PRTs, monorails, refinements to existing subway and bus systems, automated walkways, and other solutions to increasingly urban and suburban American life. The rapid rise of car ownership and driving in the same period was in some part a response to the delays that prevented transit solutions from being implemented earlier, and in part exacerbated those delays by reducing demand for public transit. As the relatively affluent middle class expanded, two-car households became more common, contributing to the tendency of suburb developers to leave transit needs barely addressed except for the question of how to get children to school.

New Technology

Apart from a few outliers that do not quite fit the ATA definition, the PRT concept may have died on the vine, at least in the United States, if not for the personal computing revolution. While the splash personal computers made is remembered now principally as being responsible for bringing computers into the home and making computer users out of computer novices, the technological revolution that was transpiring ushered in today's age of computing ubiquity. The advances that allowed computers to fit on a desk top and use a modified television as a display also allowed computers to be used for applications that previously would have been impractical. Over the course of the 1980s, the amount of computing power and memory a single device was capable of increased more dramatically than in the entire history of computers to that point.

The computer revolution changed engineering by allowing engineers to design and model systems more accurately and efficiently, while offering new possibilities for the design of control systems. Subways, buses, and other transit systems soon added magnetic-strip-based fare cards rather than the labor-intensive pass or token system of the past, and it became easier to automate other systems as well. As it did, interest was revived in PRT, leading to the discussions that culminated in the ATA's meeting. In the meantime, transit engineers and planners had learned from several decades of intensive development in a variety of communities and implementations and now had a more sophisticated sense of the populace's transit needs and of the various uses of transit systems.

On-demand service is one of the key differences between PRTs and other people mover systems. Airport people movers frequently operate on a fixed schedule: they make a circuit of the airport, stopping at each stop for about two minutes while passengers disembark or board, and do so continuously. A PRT system operates more like an elevator, but without stopping at any floors but one's own, and when not in use may either remain idle or return to a particular station, depending on the needs of the system and the purpose it serves.

PRT systems are largely hypothetical, especially going by the ATA definition. Plans for a 40-car PRT system in Suncheon, South Korea, have been delayed after an expected 2013 launch. A 10-vehicle system operates in Masdar City, United Arab

Emirates, though it has remained in the pilot stage and its announced expansion was canceled. A 21-vehicle system at Heathrow Airport in London opened in 2011 and is expected to expand. The Heathrow PRT system is developed by ULTra Global PRT, a British engineering firm branding its system as ULTra (Urban Light Transit). The electric vehicles are four-seaters with a travel speed of 25 miles per hour, a little faster than most PRT systems, and have accommodation space for wheelchairs, shopping carts, and luggage.

The pods are battery-powered and, following the ULTra design philosophy to use off-the-shelf technologies whenever possible, they use four car batteries, accounting for 8 percent of the vehicle weight. This makes for easier deployment and installation than a system that draws power off the grid, as streetcars do.

The first test track of ULTra was launched in 2002 with \$4 million in funding from the British government. Though the vehicles can handle a gradient of up to 20 percent, for passenger comfort the company recommends no greater a gradient than 10 percent. In some applications this means installing an elevated guideway in order to avoid steep ascents. ULTra was installed at Heathrow in 2010, operating 22 hours a day, seven days a week. It takes passengers from the business passenger parking lot to Heathrow's Terminal 5, 2.4 miles away. Over its first year, average passenger wait time was 10 seconds, and the system operated with greater than 99 percent reliability. It uses less than half the energy of a bus system. The planned expansion will connect parking lots to Terminals 2 and 3, and plans are considered to connect the airport to nearby hotels. ULTra has also conducted a pilot project in India.

Morgantown Example

In the United States, the Morgantown Personal Rapid Transit system has operated since 1975, connecting the central business district of Morgantown, West Virginia, to the three campuses of West Virginia University. The system covers 8.7 miles and five stations, with a daily ridership of 16,000. Development began in 1970 with a government grant to fund an experimental PRT system, and launched operations five years later. At the time it was one of many PRT experiments throughout the country, but most never saw the light of day. Over its history, it has operated with 98.5 percent reliability.



An ULTra PRT pod in a Heathrow Airport parking facility takes passengers 2.4 miles to an airport terminal in 2012. The system uses less than 50 percent of the energy of a bus system and has achieved 99 percent reliability.

Boeing, Bendix, and the Jet Propulsion Laboratory were all involved in the development of the Morgantown PRT, which was built around the Alden staRRcar system. Unlike the ULTra system, the vehicles are powered by electrified rails like many subways, driving a 70-horsepower direct current motor. In the 2000s, when Morgantown became famous for having the lowest unemployment rate in the United States, the mayor credited the PRT system for allowing the city to grow. In the late 1990s, the original DEC PDP-11 computers used to control the system were replaced with Intel Pentium devices.

By the ATA definitions, the Morgantown PRT system is not a proper PRT system. The 15.5 by 6.6 feet vehicles accommodate up to 20 people (with eight seats and standing room for the rest), and in fact there is an annual college student event called

the PRT Cram in which student organizations compete to fit as many people as possible into a PRT car (2000's record of 97 has not been beaten). Further, when there are more than a few people, the car becomes a normal people mover, going from one stop to the next instead of taking its passengers on a nonstop direct trip.

Because it can and does act like a PRT system for part of the day, the Morgantown system may be thought of as one that switches between a PRT system and a normal people mover, in response to conditions. During peak hours, when cars carry larger numbers of passengers, it operates in schedule mode, following a fixed route. During off-peak hours, the system operates in both demand mode and circulation mode.

In circulation mode, a smaller number of vehicles follow a fixed circuit, stopping at every station. In demand mode, when a rider requests a car through a call button, a vehicle is activated either after a specified period of time (usually five minutes) or once enough passengers have requested service, whichever threshold is passed first. Because it does not run late at night or on Sundays, it also fails the ATA's 24–7 requirement. Systems like Morgantown's, which are influenced by PRT designs but differ from the typical PRT in capacity, are sometimes called Group Rapid Transit.

Benefits

Ideally, the strength of a PRT system beyond its efficiency and low operating cost is its passenger-driven demand-based approach. The more stations the system serves, the more this is an advantage to the passenger, who can travel to any station directly, with minimum waiting and travel times. The small capacity of the cars also means that a larger share of the cars travel at full capacity, increasing their operational efficiency. The smaller vehicles also mean the guideway and right-of-way requirements are substantially smaller than for other forms of transit—this is especially true at the small end of the spectrum like ULTra's podcars, but even Morgantown's system has reduced space requirements compared to a subway system. These reduced requirements make planning and implementation easier, and increase substantially the existing spaces into which a PRT system can fit.

That ease of planning fits well with what ULTra and other systems have shown—that a healthy and

effective PRT system can be constructed with off-the-shelf technology. This means firms can design and deploy PRT systems with less human and intellectual capital, not only reducing costs but reducing the amount of time it takes to develop such a system. The main source of delays in deploying and expanding ULTra, for instance, have been at the customer end of the relationship, because of the bureaucracy involved and the planning sessions that precede such decisions.

PRT systems also have the advantage of being able to be implemented incrementally; by their nature, they are well suited to expansion, which should encourage communities to be willing to adopt them on a small scale without worrying that they need to debate the merits of a larger-scale implementation first.

While PRT systems outside Morgantown have mainly been implemented to serve specific commercial purposes, such as transit to or within the grounds of an airport, they have potential as primary transit systems. PRT systems are more affordable and within the reach of smaller cities like Manchester, New Hampshire; Billings, Montana; or Denton, Texas, which are too small to warrant other rail systems but which would benefit from increasing their city's transit accessibility. PRT systems can also augment existing transit systems, providing feeder systems from outlying communities or targeting specific routes or populations, such as on-campus student residents, retirement communities, or new residential neighborhoods.

Conclusion

Before the worldwide financial crisis of 2008, there were several plans to develop or pilot PRT systems in various American communities, notably as part of the Skyloop in Cincinnati, Ohio, and in California's Silicon Valley. The subsequent depression canceled, delayed, or postponed many of these plans, and while the federal stimulus package of 2009 earmarked about \$27 billion for transportation projects, states chose to spend most of this money to build new roads and other motor vehicle infrastructure. Since then, however, the ULTra system at Heathrow has brought attention to the concept, and progress has slowly begun again.

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See Also: Automated Guideway Transit; Automated Transit Systems; Personal Transportation Systems; Railroad Automation Technology.

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Personal Transportation Systems

A personal transportation system is one that transports only the driver or operator, without passengers or freight (beyond what is carried on the person, such as a backpack). This can include bicycles and other human-powered devices, and is especially used to refer to motorized single-person transporters such as the Segway PT, introduced in 2001.

The Segway PT was one of the most highly anticipated new products at the time of its release, because of a powerful prerelease publicity campaign that did not even reveal the name of the product, referring to it only as "IT." Much of the publicity was inadvertently blown out of proportion after leaks from an unreleased book about the Segway's development, which, out of context, made the device seem more significant than it was prompted a hype-prone press to speculate that IT, whatever it was, would be as culture-changing as the Internet or the personal computer had been.

The public unveiling was televised on *Good Morning America*, and IT was revealed to be a motorized one-person platform with gyroscopic and leveling sensors to both keep the device upright and allow the operator to steer the device by shifting weight forward or backward. Steering is accomplished via a handlebar. Speeds approach 12 miles per hour (mph).



A wounded veteran stands on a Segway personal transportation device at a demonstration for the U.S. Marine Corps in Arlington, Virginia, October 6, 2010. A group called Disability Rights Advocates for Technology has pressed for more communities to maintain sidewalk and building access for personal transporters as a requirement of the Americans with Disabilities Act (ADA). In 2011, an amendment to Title II of the ADA led to Segway use being permitted under the class of "other power-driven mobility devices."

The Segway is electric and uses lithium-ion batteries, which are recharged by plugging into an ordinary household outlet. They have not been approved for marketing as a medical device, and they cannot be sold as one for insurance purposes. Dean Kamen, the Segway's inventor, sold the medical rights to the underlying technology (originally used in the iBOT self-balancing wheelchair) to Johnson & Johnson, preventing him from pursuing this route with the Segway.

Nevertheless, the Segway, like other personal transporters, has found a following in the disabled community, and the group called Disability Rights Advocates for Technology has pressed for more communities to maintain sidewalk and building access for personal transporters as a requirement of the Americans with Disabilities Act (ADA). On the other hand, the American Council of the Blind has

opposed efforts to increase Segway use, arguing that their use creates an environment that is more dangerous for the blind and makes collisions—which, while frightening, rarely lead to injury when they are between pedestrians—more serious, because of the increased weight and, especially, the higher speed of the Segway in comparison to a human.

In 2011, an amendment to Title II of the ADA permitted Segway use under the class of "other power-driven mobility devices," without reference to the medical-device criterion. However, not all jurisdictions have updated their laws to include this class, and the amendment provides some leeway in interpretation.

Personal transporters are widely used by police and private security forces, and they are sometimes rented to tourists in theme parks and other similar attractions as an alternative to pedestrian

travel. Personal transporters are usually considered a means of travel suited to sidewalks rather than streets, although the legality of street travel depends on the location.

The motorized personal transporter does not generally require a license or vehicle registration, though an age restriction on the operator may apply. In some jurisdictions, Segways are classed as vehicles or alongside another vehicle type. For example, in Japan and Switzerland, it is considered a type of motorcycle; in much of central and eastern Europe, it is grouped with bicycles and pedestrian traffic, and where one is legal, so are all three; Denmark classifies motorized personal transporters as mopeds, requiring mechanical brakes, lights, and a license plate; and Sweden has classified personal transporters as bicycles since 2010, having previously banned them on public pavement (whether road or sidewalk).

In North America, personal transporter policy is left to local authorities. Few Canadian provinces permit personal transporters on public roads, limiting them to private property. In some jurisdictions, they are not even allowed in bicycle-designated areas such as paved bicycle paths. The province of Ontario has operated a pilot program permitting Segway street access to people who are disabled, postal carriers, and police officers, but participation has been low.

In the United States, the Segway's inability to be classified as a medical device has led to its default ban from sidewalks and on public transportation in many areas where medical devices are the only forms of transport exempted. Few states ban their use on sidewalks, leaving the matter for individual municipalities to decide. Most states either permit the use of Segways in bicycle lanes, on bicycle paths, and on roads with a posted speed limit of 25 mph or lower, or do not specifically ban them; again, within each state, individual municipalities may, and often do, pass more restrictive regulations. In some cases, use of Segways in public areas is limited to daylight hours.

In Disney-branded theme parks, personal Segways and other personal transporters (if not classed as medical devices) are banned, but the parks provide guided Segway tours for a fee. This approach has been adopted by other theme parks.

The Segway is the market leader in motorized personal transporters, and the name has become,

to a large extent, the default term for them. However, other brands are available. Honda's U3-X released in 2009 is a self-balancing, one-wheeled vehicle based on technology originally developed for a bipedal human-like robot. It is smaller than the Segway and fits between the operator's legs, but also has a much lower speed, comparable to fast walking (about 3.7 mph). The Toyota Winglet, developed at about the same time but not yet released to consumers, is similar, using two wheels but achieving the same speeds as the U3-X. In 2012, Personal Rover released its device, which is similar to a motorized skateboard with handles resembling ski poles that are used to maneuver. This product is available at a lower price point than most of its competitors.

Personal transportation systems also include powered wheelchairs and mobility scooters. Mobility scooters have become popular choices for the elderly and those with significant arthritis or respiratory issues who are capable of mobility but benefit from assistance or tire quickly, particularly in circumstances like shopping or visiting parks. Many supermarkets and malls now provide mobility scooters of three-, four-, or five-wheel designs. This service is especially beneficial because Medicare does not pay for powered wheelchairs (of which scooters are considered a subset) for individuals who do not need them inside the home.

Several single-person cars are subject to the same safety regulations as other automobiles. They include the Formula Ford race car, a training race car with safety modifications to make it street legal; the Exomotive Atomic, which resembles a small low-riding dune buggy and has the motor in the passenger space; ultracompact vehicles like the open-design SUB Motorsports three-wheeler (resembling a kayak with wheels); and riding lawnmowers modified to meet road-use regulations. Hitachi has also developed the Ropits (robot for personal intelligent transport systems), which provides sidewalk transportation for the elderly and disabled in the form of covered self-driving motorized scooters.

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See Also: Light Electric Vehicles; Pedestrian Travel; Personal Rapid Transit.

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Pipeline and Hazardous Materials Safety Administration

The Pipeline and Hazardous Materials Safety Administration (PHMSA) was created under the Norman Y. Mineta Research and Special Programs Improvement Act of 2004 as an agency of the U.S. Department of Transportation (DOT). PHMSA is responsible for creating and enforcing regulations to ensure the safe and dependable operation of the country's more than 2-million-mile natural gas and hazardous liquids pipeline transportation system. It also has regulatory oversight of the daily volume of nearly 1 million hazardous materials shipments carried by land, sea, and air across the United States. The regulations are designed to protect people, the environment, and the transportation industry from risks associated with the transport of hazardous materials.

Hazardous materials quite literally fuel the U.S. economy and are essential to maintaining quality-of-life standards. Oil and natural gas are used to produce electricity, heat and cool residences and businesses, transport people and products, and provide feedstock for a number of other commodities. Hazardous materials are also used in the purification of drinking water for human consumption, fertilization of agricultural crops, production of pharmaceutical drugs, and manufacture of apparel and other goods.

Relying on hazardous materials for so many critical functions comes with risks, especially those

associated with transporting hazardous materials from one location to another. The PHMSA regulations are designed to protect people, the environment, the transportation industry, and the economy from those transit-related risks.

Structure and Role

PHMSA is headquartered in Washington, D.C., and has regional representation across the United States. Operations are divided into two designated safety offices—the Office of Pipeline Safety and the Office of Hazardous Materials Safety—which are overseen by an administrator appointed by the president. Support is provided by a senior leadership team and nearly 500 employees agency-wide.

PHMSA's primary focus is on safety. Among its key responsibilities are establishing national hazardous materials transportation policy, and setting and enforcing standards designed to eliminate deaths, injuries, incidents, and damage to the environment and property as a result of hazardous materials conveyance. PHMSA also works to reduce dangers and harmful consequences to individuals, the environment, the transportation industry, and the economy at-large following a hazardous materials accident or pipeline failure. In the case of states, communities, and population groups that require financial and technical assistance to become prepared for hazardous materials emergencies, PHMSA awards special grants.

The organization proactively sponsors research projects related to advancing technologies that have potential application for enhancing hazardous material and pipeline safety procedures. PHMSA also distributes special permits, guidance documents, and informational materials to improve education, and administers a toll-free telephone information center that enables anyone to ask questions, order publications, and report safety violations of PHMSA regulations. For travelers, the agency provides continuously updated safety guidelines regarding personal transportation of materials that may be hazardous or contain hazardous components, such as batteries and battery-powered devices.

Outside the United States, PHMSA participates in an ongoing initiative aimed at standardizing pipeline and hazardous materials transportation requirements across the globe. It also works with agency counterparts in Canada and Mexico to coordinate consistent North American guidelines

for firefighters, police, and other emergency services workers who are likely to be among the first responders to a hazardous materials accident. At U.S. ports of entry, PHMSA facilitates the safe and orderly transport of hazardous materials.

In the area of enforcement, the organization conducts drug and alcohol testing of personnel who transport hazardous materials, and ensures compliance with safety and training standards by way of conducting field inspections of shipper and carrier transportation facilities; manufacturing, packaging, repairing, and reconditioning work areas; cargo vessel ports; rail freight yards; motor carrier and air cargo terminals; and chemical and explosives manufacturing plants.

Accomplishments and Challenges

Through the work of the DOT, and later joined by the efforts of PHMSA, the risk of hazardous materials transportation incidents resulting in death or major injury was reduced by 4 percent every three years between 1988 and 2011. Similarly, the risk of pipeline incidents leading to death or major injury was lowered by approximately 10 percent every three years in the same timeframe. Since 2002, the risk of hazardous liquid pipeline spills with environmental consequences has receded by an average of 5 percent each year.

Building on its long history of success, PHMSA set stringent safety and environmental goals to achieve by 2016. Specifically, the agency seeks to further reduce the number of fatalities and serious injuries from hazardous materials and pipeline incidents each year to below 38. It also wants to reduce environmentally damaging hazardous materials and pipeline incidents each year to less than 65 and 82, respectively. To achieve its goals, PHMSA will have to address a number of challenges in the areas of infrastructure, product evolution, technology advances, and human factors.

With population growth, energy consumption, and chemical production expected to rise, the exposure to risk from incidents involving hazardous materials and pipelines is also likely to rise. The U.S. Department of Energy (DOE) forecasts a potential 13 percent to 27 percent increase in risk exposure through 2015.

PHMSA is adapting to the growth and geographic shifts in population by requiring businesses to account for population exposure through their own

risk management programs, meaning that pipeline companies must consider population exposure as part of their integrity management programs and when classifying lines for transmission of natural gas. In addition, PHMSA has put hazardous materials transit through high-population areas under closer scrutiny, with stricter technical requirements, route restrictions, and safety inspections.

With approximately 17 percent of natural gas and hazardous liquid pipelines greater than 50 years old or of unknown age, and another 8 percent constructed of erosive materials, the pipeline infrastructure itself poses another challenge for PHMSA. The agency works with state pipeline safety programs and pipeline operators to accelerate the identification, repair/replacement, and requalification of the pipelines posing the highest risks. It is also researching new technologies designed to enhance the ability to identify, assess, and control pipeline risks.

Among the leading causes of safety incidents resulting in death or major injury are pipeline material failure, corrosion, and damage to pipeline integrity from excavation or another external force. To reduce the occurrence of compromised pipelines from such causes, PHMSA has expanded its safety inspections, targeted research, and established the 811 Call Before You Dig program, which encourages excavators to call for information before they break ground. The organization also is proactive in promoting best practices regarding land use planning and development near transmission pipelines.

Crashes and rollovers involving tank trucks carrying gasoline and other flammable liquids account for approximately three-quarters of gasoline-related fatalities, and they rank as a leading cause of injury and death from hazardous materials transportation. Such accidents also can result in spills that prompt highway closures and environmental contamination. PHMSA works with the National Highway Traffic Safety Administration and the Federal Motor Carrier Safety Administration to draft standards for electronic stability control for trucks, and with other DOT agencies to provide enhanced tank-truck driver training, as well as to find ways to reduce driver fatigue.

Bulk transportation of hazardous materials that are toxic by inhalation, such as chlorine, is also on PHMSA's radar. While it is a very low-probability risk, it has extremely high safety consequences,

regardless of mode of transport. A similar low-likeness, high-toll risk is that of fire aboard an aircraft involving hazardous materials.

To address these potential risks, PHMSA has developed standards for loading and unloading bulk hazardous materials and for transporting flammable and combustible liquids and lithium batteries aboard aircraft. The agency also facilitated the development of advanced rail tank cars dedicated to bulk transport and is working to synchronize U.S. domestic regulations with international standards for air transport of hazardous materials.

PHMSA is increasing its safety focus beyond compliance with standards by promoting the development of a strong safety culture within the companies it regulates, and it is evaluating the use of management systems for safety, quality, and control-room risk mitigation due to human error. It is also targeting research into products, processes, and technologies that have the potential to provide safety benefits in hazardous materials and pipeline transport operations. At the same time, PHMSA is directing resources to expand overall research capacity and quality of data to better target and, thus, manage the most serious real and potential safety risks.

While the agency's primary focus is on incident prevention, it must also ensure that a strong and effective response capability is in place to reduce harmful outcomes. Toward that end, PHMSA has built in secondary containment requirements that limit the disbursement of hazardous materials in the case of primary packaging failure, improve leak-detection and shutoff control systems for gas and liquid pipelines, and advance the development of electronic shipping papers to improve access to and use of hazardous materials communication when an incident occurs. PHMSA has also worked to increase coordination, collaboration, and accountability among emergency responders, and to refine emergency response definitions and standards.

Need for Collaboration

The reduction of risks associated with pipeline and hazardous materials transportation is not solely the responsibility of PHMSA. While the agency serves in a leadership capacity, other federal agencies, state and local groups, international organizations, domestic businesses, and public citizens all have roles to play.

Federal, state, and local agencies provide essential support for PHMSA's programs in regard to

education, execution, and enforcement, while U.S. and international businesses hold primary responsibility for the safety of their own operations. The public's main role in hazardous materials and pipeline safety is awareness. People should be alert to potential risks and consequences and be cognizant of the extensive efforts being made within both the public and private sectors to ensure safe standards, practices, and accountability.

For its part, PHMSA is dedicated to gaining a better understanding of and target on safety risks by bolstering safety standards and enforcement, promoting a strong safety culture and systems, leveraging technology and research, optimizing effectiveness of collaborations, and expanding public education and awareness.

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See Also: Aviation Safety, Dangerous Goods Transport and; Emergency Response Systems; Freight Transport, Security Issues; Hazardous Materials Transport; Risk Analysis/Assessment; U.S. Department of Transportation.

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Planning, Programming, and Budgeting Systems

The use of Planning, Programming, and Budgeting Systems (PPBS) techniques in transit administration evolved during the 1960s and 1970s in the

United States. It was a means of organizing the essential processes that transportation authorities and policy makers needed to undertake in order to craft new systems and upgrade existing networks in a manner that would deliver maximum service benefits while keeping capital investments and operating costs under control.

Three Essential Steps

PPBS has been somewhat superseded by a range of other process-control methodologies in use by transportation administrators, although its key principles remain valid. The value of the PPBS process and the documents it generates can be useful whether the budget output represents the plans and programs of a public body or a private enterprise.

The first P—the plan—is the initial step in the technique. Data on goals, capabilities, material and personnel needs, and similar matters are gathered from the field operations staff. At the same time, directives and compliance requirements, along with strategic goals, are received from the oversight and funding authorities. Together, these criteria are synthesized into the plan. This is typically done at the very outset of a project and must then be repeated on an annual basis. Sometimes institutions or agencies also require three-year, five-year, and 10-year plans in order to build greater strategic vision, as well as to meet the more practical challenges of long-term budgeting, borrowing, and the effects these have on day-to-day operational capabilities, service levels, staffing, and related functions.

Once the plan is prepared, the key elements of the plan are input through various methods and practices to assemble the program, which is the second P. In this undertaking, it is recognized throughout the process that the output of this step will lead to the budget. Therefore, formats are structured with that goal in mind. The programming of the plan must be immediately recognizable, and its content readily accessible, to facilitate its use by both the internal and external financial administrative staff.

Programming typically features an overview, rosters of key decision makers and details on their staff complement and capabilities, an outline of timeline goals and milestones to enable monitoring of program progress once it is put into effect, information on internal and outside resources that will be called on to accomplish the plan at its different stages, and

any fiscal year carry-forwards or other fiduciary ramifications that will need to be discovered and explored in the budgeting segment of the process.

The B, or budgeting segment, is the presentation phase of the PPBS sequence, in which priority aspects of the plan, along with the major stages of the program, are translated into a codified, comprehensive statement of the expenditure and funding requirements for both long-term capital investment (e.g., right-of-way acquisition, infrastructure construction, and rolling stock purchase) and operational costs (e.g., workforce, contractor payments, utility and supply costs, and expense reimbursements).

The budget thus becomes the closest-to-reality component of this process. In its line-item translation, it serves as a dollar-and-cents statement of the strategic goals of the plan, as well as the toolkit of metrics encompassed in the programming. The budget provides the truest measure of the ways and means necessary to accomplish strategic goals and their everyday application, and the budget spells out the grants, loans, and ongoing funding streams that must be negotiated with targeted financial sources.

In this way, the budget of a public transportation entity also becomes the template for negotiation with the funding, administrative, regulatory oversight, and enforcement authorities of the enabling legislation.

Stages and Phases

Transit system planning is an extremely complex undertaking in which there is no single system applicable to all circumstances or markets. This has become increasingly clear especially in the context of the mandating of closer working relationships among federal, state, regional, and local transportation planners and a growing array of external constituents. These may include major industrial companies, service corporations, private or public real estate developers, energy and fuel providers, operators of the full range of transportation modes separate from that being planned, local homeowners associations, environmental protection groups, cultural preservation organizations, health care bodies, organized labor, media outlets, merchants associations, and both elected and appointed political bureaus and figures.

The integration of public-private partnership (P3) initiatives into planning has added yet

another layer of complexity, albeit one that often yields benefits to the planners. Beginning in the 1980s, the federal transportation leadership in the United States became more insistent on this front, impressing through a variety of documents, policies, and reports that P3s must be pursued to “capitalize on opportunities to integrate transit facilities into major new developments” by being “more aggressive in working with developers and local governments in growing parts of metropolitan areas,” as it was put in a U.S. Department of Transportation (DOT) recommendation issued in conjunction with the independent Transportation Research Board.

This trend was in no small part driven by harsh pressures on raising and maintaining funding levels for transportation projects; state and federal governments in the 1980s were generally faced with declining tax revenues as measured against rising funding mandates for non-transportation budgets, as well as historically high levels of inflation and its impact on borrowing rates. In some cases, planning authorities are legally mandated to pursue relationships with certain categories of constituents. In terms of the PPBS process, such constituents are partly transformed, in a sense, from external to internal considerations. The ramifications of various P3 activities must be incorporated into the planning, the programming, and the budgeting process.

Practical Matters

In the PPBS approach to strategic transportation system administration, the process must start with a comprehensive understanding of transit operations. This includes mastery of the methods and economic evaluation of scheduling vehicles and personnel, line capacity, the use of intelligent modeling in the analysis of design options and operational phases of a transit system, determining station locations and layouts, finding ways to increase operational efficiency and measure same, internal organizational structure, relations with labor and passenger populations, information technology advances, ticket tech, and fare dynamics.

Planners must also analyze and build in measures for meeting regulatory compliance standards and schedules, as well as the intricacies of varied sources of financing within and external to government bodies. In covering these criteria—essentially the practical building blocks of transit planning and

operations—many ratios and metrics are used to evaluate and balance such functions as improved service, fare revenues, transit speed, and customer satisfaction. These criteria, and the means to measure them, ideally will have been built into the system from the outset, through application of PPBS.

For example, one essential metric is level of service (LOS). This can be measured by a comparison of data on functions such as travel time, reliability, comfort, and the quite testable ability of a system to attract and keep passengers over time.

A core component of LOS is service quality, which itself is a compilation of the qualitatively examined aspects of service as experienced by the passengers. These include cleanliness, perceived safety of the system, aesthetics and ease of access to information, average seat availability, average wait time, riding comfort, convenience factors, fare prices and programs, and overall perception of value.

Modifications and Improvement

Although the PPBS approach continues to provide some fundamental ways and means of transportation system administration, the process has been faulted to some degree for a perceived lack of emphasis on quantitative and qualitative measurement and evaluation of outcomes. The types and scope of measurement and evaluation protocols that are more frequently applied tend to examine the execution, adjustment, and follow-through actions needed to provide a more holistic, closed-loop system that is thought to better support a strategic administrative approach. Thus, PPBS has in many cases been superseded by a PPBE approach, where the E is understood to mean “execution”—of the plan, of its components, and, particularly in complex and ongoing multiyear situations, of adjustments made to the original plan or plans.

The transition to PPBE was officially made during the 2002, 2003, and 2004 fiscal year periods, for example, by federal agencies including the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, and the Department of Defense (DOD). The DOD in its process noted the utility of PPBE as a means to “streamline connection between priorities and decisions,” and for its application as a way to improve “cost-benefit analysis of alternative programs” over the course of multiyear continuous budgetary regimes. PPBE in

sum is seen as a more reliable, flexible, and dynamic tool to provide feedback that compares and contrasts planned programs with real-world resource availability, actual performance, and changing conditions. Used appropriately, especially in high-level strategy planning and budgeting, PPBE can yield more transparency in links connecting expenditure, revenue, and related metrics.

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See Also: Integrated Transportation and Urban Land Use Planning Models; State Implementation Plans; Transit Management and Operations; Transit Planning, International; Transportation Modeling and Planning Software.

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Pneumatic Tube Transportation

Pneumatic tube transportation systems use compressed air to transport objects through a system of closed tubes. A basic system consists of two stations connected by a tube, with one station including an air compressor that is used either to create a vacuum to draw the object into the station or to create propulsive force by blowing air to push it away to the other station. Pneumatic tube systems have historically been used as a communication system and transport system in large buildings and as a method of delivering mail in cities.

Although various pneumatic tube train systems for human transportation have also been proposed, and a few actually built, all working systems have covered short distances and are no longer in operation. Different systems for human transport through evacuated tubes have also been proposed, but no working models have yet been built.

Transportation of Items

In the late 19th century, pneumatic transportation systems were commonly used in large department stores, mainly to transport money (hence, the term *cash carrier*) and small items or paperwork (for example, order slips) throughout the store; the items were placed in small capsules before being transported through the tubes. In terms of carrying cash, pneumatic tubes were a refinement of an earlier system that used cash placed inside wooden cylinders, which were rolled down sloping rails between the cash office and sales desks. The first patent for a department store pneumatic transportation system was granted in 1875, and the system was adopted in many large department stores by the 1880s.

The invention of the cash register reduced the need for the cash carrier systems, while self-service



In 1943, the passenger agents' room in Union Station in Chicago, Illinois, featured this pneumatic tube system, which rapidly delivered reservation diagrams for trains to Pullman porters.

stores reduced the need to transport order slips or small goods by this method. Yet, they are still used in some places (for example, J & R Electronics in New York City). Pneumatic tubes are also used for special applications, including transferring money and paperwork within casinos, where the extra security of a closed system is valued; and transporting medications, blood samples, and other small items through hospital systems, where both security and speed in handling physical items are valued.

The Central Research Library (now the Stephen A. Schwarzman Building) of the New York Public Library System used a pneumatic tube system to transport call slips from its opening in 1911 until 2012, facilitating rapid communication between the main reading room and the book stacks. Patrons filled out a paper call slip requesting a book or

journal, it was placed in a metal capsule, and the capsule was delivered pneumatically to employees working in the stacks, who would retrieve the requested items and place them in a dumbwaiter for delivery to the patron in the reading room.

Pneumatic tube systems were also used to deliver mail. Philadelphia was the first U.S. city to use this system, beginning in 1893, and Boston, New York, Brooklyn, Chicago, and St. Louis also built pneumatic mail-delivery systems. By 1915, the U.S. Postal Service estimated that, together, those cities had over 56 miles of underground pneumatic tubes used for mail delivery, with 27 miles in Manhattan, New York, alone.

The New York City system operated at 30 miles per hour (mph) and reached from Lower Manhattan to Harlem and across the Brooklyn Bridge to the main Brooklyn Post Office. Pneumatic mail service in the United States was suspended during World War I, then restored in Boston and New York, where it continued to operate into the 1950s. Several large European cities also developed pneumatic postal delivery systems, including London, Berlin, Paris, and Vienna. The pneumatic postal delivery system in Prague was completed in 1887 and remained in use until the 2002 floods put it out of operation; notably, the mail tubes were used during the Prague Uprising of 1945 to transport supplies.

Human Transportation

The concept of using pneumatic tubes to transport human beings has been used by several science fiction writers, from Jules Verne in *Paris in the 20th Century* (1863), which imagined pneumatic tubes undercrossing the Atlantic Ocean, to Neal Stephenson in *Downsiders* (1999), which imagines a colony of people called “downsiders” who live beneath the surface of New York City. It is noteworthy that Stephenson brings in the ideas of Alfred Ely Beach, an early publisher of *Scientific American*, who imagined a system of pneumatic tubes providing public transportation beneath the streets of New York City.

Beach actually began construction on his project, called the Beach Pneumatic Transit, constructing a tunnel under Broadway in Lower Manhattan for this purpose. A section of the railway opened to the public in 1870, operating a train over a one-block stretch of track as a demonstration project for the proposed system. However, the project was

delayed by official obstruction followed by a stock market crash, and it was never expanded.

In England, a pneumatic railway was built in 1864, designed by Thomas Webster Rammell and running for about 600 yards between two entrances to Crystal Palace Park in London. This short railway did open and carry passengers, but it was intended primarily as a demonstration project for a longer railway to run under the Thames River, which was never constructed.

Several research groups are working on the possibility of developing modern pneumatic railways through vacuum tubes, sometimes called “vacitrains.” However, although these systems are founded on the concept of transporting a capsule car carrying goods or people through a vacuum tube, the key purpose of the vacuum is to remove air resistance and thus enable faster travel with less expenditure of fuel.

The mechanical engineer Daryl Oster, founder and chief executive officer of ET3, is a contemporary advocate for the viability of vacitrains, which he calls evacuated tube travel (ETT) transportation systems. Oster’s idea is to use magnetic levitation (maglev) to transport car-sized capsules carrying six people or 800 pounds of cargo through evacuated tubes 5 feet in diameter.

The capsules would be started on their journey using electric motors and would coast through the tubes for most of the journey, regenerating most of the energy used as they slow down. If implemented, this would be more energy-efficient than any current system of vehicle transportation. However, this project remains at the level of theory, with no prototypes in operation to allow reasoned evaluation of the prospects for this type of transportation system.

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See Also: Maglev Systems; Railroad Automation Technology; Supply-Chain Management; Transit Tunnels, Design and Construction of.

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Port Facilities

Ports are human-built facilities alongside which ships can be loaded or unloaded using cranes or, in the case of container ports, gantries. A port consists of quays and jetties where ships are tied, together with storage facilities for goods; larger ports also have transport connections to roads or rail systems. Some coastal ports also have access to waterways or canal systems on which goods can be transported inland by ship, boat, or barge.

Container ports are generally ocean or sea ports, although some very large ports are located along rivers. Examples include Rotterdam in the Netherlands (ranked 10th in the world for volume of goods throughput in 2011) and Tianjin on the River Haihe in China (ranked 11th). With the development of containerization have come larger ships, some of which can carry over 16,000 TEU (twenty-foot equivalent units). Consequently, larger cargo cranes and gantries have been developed to handle those ships.

History of Cargo Cranes

Prior to the introduction of containers to transport a wide range of bulk cargos, dry goods, and even food and perishable items in refrigerated containers, cargo was transported loosely in the holds of ships, on pallets, or in bales. It was a lengthy process to load and unload cargo and equipment in ports. Because the equipment, usually some type of crane, was often fairly basic, ships could spend

considerable periods of time being unloaded, and then be carefully reloaded before they could sail to their next port of call.

Historically, the first mention of cranes appears in writings from ancient Greece, although mechanisms to lift objects existed long before that. Leonardo da Vinci both described and designed cranes in the 15th century. Many of the cranes used by ports in the first half of the 20th century were little changed from those early designs, constructed in wood and using human-powered winches to lift cargo from ships. Early mechanized designs appeared in the mid-19th century that used steam power, for example.

In 1956, Malcolm McLean, a trucking company owner from North Carolina in the United States, operated the first ship converted to carry standard containers that could be easily transferred from truck to ship and vice versa. McLean had purchased a small shipping company in 1955, and his combination of road and shipping companies can be viewed as an early and small-scale example of what would become known as an intermodal transport network. In such a system, the same cargo is carried in a single container from point of origin to final destination without the need to remove it from that container.

The introduction of shipping containers in 1956 was a turning point for the transportation of cargo. It made it possible to load and off-load containers rapidly so that ships had to spend less time in port and, as a result, more perishable goods could be transported. Containers could be stacked inside the holds and on the decks of container ships, and could be transferred directly from ships to trucks or railcars within a container terminal. A revolution in the global transportation of goods commenced, with ships increasing in size and new ports being built in China, southeast Asia, and the Middle East, for example. Today, container ports are distributed across the globe, and many millions of containers are transported by sea each year.

Cargo Cranes and Gantries

In simple terms, cranes are machines that use a system of pulleys or levers to lift large weights. Cranes are generally either diesel-powered, with a diesel engine situated on the crane structure, or electric-powered, connected to a power source on the quay. Cranes can either be fixed in place on the

quayside, or they can be mobile and moved around the port to wherever required. They can be fitted with standard tires to run on roads or with wheels that are designed for use with railroad tracks. They can also use caterpillar tracks (continuous tracks like those used on tanks).

A cargo crane basically consists of a base, which can be any height or shape, from which a jib (boom or arm) extends out at an angle. In some cranes, the angle of the jib can be adjusted. Larger cranes can have a telescopic boom that can be extended so that cargo or containers can be loaded or off-loaded across the entire width of a ship.

From the jib is suspended a lifting mechanism such as a hook or crab (a grabbing tool), which is connected through a single cable. On this type of crane, the lifting mechanism is raised and lowered using a system of pulleys and connected to the cargo or load to be lifted. The boom can be rotated on a turntable, either at the bottom or top of the base, so that the cargo can be swung around and then lowered onto either the quayside or a waiting truck. However, a potential problem with this type of single-cable crane is that the container or cargo suspended at the end of the cable may start to swing or twist, particularly in windy conditions, and so may be difficult to control.

A standard gantry crane (or container-handling gantry crane) consists of one or more rectangular frames with a trolley (or cabin) suspended under the horizontal boom (a crosspiece or bridge) on rails that run underneath or on the side of that boom. The trolley is able to move laterally (left to right and vice versa) and is controlled by a driver sitting in a control cabin on the trolley. A moving hoist, known as a spreader, is suspended beneath the trolley and can be raised or lowered vertically on at least two cables, giving it greater stability than single-cable cranes.

In order to unload a container, the hoist is lowered and attached with locking screws or mechanisms at all four corners of the container, which is then lifted vertically until free of any obstruction. The trolley then moves laterally until it is over the truck, railcar, or container stack. Some gantry cranes are mobile—either rubber-tired gantry cranes (RTGs) or rail-mounted gantry cranes (RMGs)—and can move around with the container suspended underneath until it reaches its required destination.

A gantry crane designed to load and unload ships (ship-to-shore gantry crane) can be moved along the quayside to come alongside a ship, or the ship can tie up next to the crane. This type of gantry crane differs from the standard version in that it has an extended crosspiece that extends out beyond the edge of the quay, allowing the trolley to move above the ship and unload containers across its full width.

Container ships have grown in size since the gantry-crane concept was first developed, when ships and cranes were categorized based on a measure originally established for the size of ships able to travel through the Panama Canal. In reference to the canal, Panamax cranes can unload ships that are between 12 and 13 containers wide, while Post-Panamax can extend to roughly 18 containers wide. The Super-Panamax has a range up to 22 containers wide.

As ship sizes have grown, so have the size and lifting capacity of cranes. Some modern cranes can lift up to four 20-foot-long or two 40-foot-long containers simultaneously, and some can lift weights to 120 tons. There are also cranes with a jib radius (the distance the crane's arm or gantry boom can reach) of up to 120 feet (36 meters), enabling them to lift containers from the widest Super-Panamax containerships.

With all cranes, it is critical to know the weight of the container to be moved. Cranes with long jib arms or telescopic jibs may overbalance if the weight is excessive. Similarly, the structural integrity of a gantry crane may be compromised if the weight is too great, particularly if the trolley is at the farthest limits of the crosspiece, causing its rectangular frame to bend or break.

Containers are generally measured in terms of their size and volume, such as 20-foot equivalent units (TEUs) and 40-foot equivalent units (FEUs), and it is very important to know the actual weight of the containers to ensure that they can be lifted safely.

Gantry cranes are an essential tool in ports to ensure the efficient loading and unloading of cargo and the movement of containers around the port area. However, it is unclear how much larger it is possible to build cranes, particularly for existing container ports that might not have sufficient space to accommodate larger cranes. Developments in electronic tracking of containers, to both map their location and plan the most efficient routes for

cranes to move through the port area, may be the next stage in ensuring the rapid throughput of containers that is so vital for ports to be competitive in the global arena.

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See Also: Container Terminals; Containerization/ Container Shipping; Freight Transport, Intermodal and Multimodal; Harbor and Port Planning; Ships; World Container Ports.

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Port Inspections

Port inspections fall into two categories: (1) those directed at the port area and cargo or containers, executed to ensure their safety and to search for smuggled goods such as drugs, weapons, or individuals; and (2) those directed at ships using a port. In the former case, for the majority of ports, inspections are carried out under international rules set out and administered by the International Maritime

Organization (IMO), while additional security measures are in place for container ports that trade with the United States.

In the latter case, those inspections examine the ship to ensure that it is seaworthy and safe to travel to its next destination, that it is in compliance with a range of international conventions and regional measures, that crew conditions are satisfactory, and that it does not pose a risk to the environment from pollution. A number of regional bodies have been established around the globe to conduct those inspections and to ensure a safe and secure maritime transport industry.

Securing the Port Environment

Following the attacks on the United States on September 11, 2001, there was a growing perception that seaports, and particularly container ports or those receiving petroleum and gas products, could be a target for terrorist activities. As a result, in 2004, a new chapter was added to the 1974 International Convention on the Safety of Life at Sea (SOLAS), one of the conventions administered by the IMO, the agency of the United Nations responsible for the safety and security of shipping and the prevention of marine pollution from ships, for example. That new chapter is SOLAS Chapter XI-2, which sets out special measures to enhance maritime security. In addition, the IMO introduced the International Ship and Port Facility Security Code (ISPS), a framework for governments, ships, and ports to work together to detect and deter threats to maritime transport.

The ISPS Code comes in two parts. Part A, which is mandatory for all countries that are signatories to the SOLAS Convention, requires those signatory states to ensure the security of ships and ports through the use of risk assessments, and also requires both ships and ports to appoint a security officer and to develop a Security Plan. Part B provides guidance on how to implement Part A. Signatory states are involved in setting security levels on ships and in ports if a threat is identified, and in communicating those security measures as necessary.

Ports that fall under the ISPS Code are required to have a security assessment conducted by a recognized security agency. This assessment should cover areas including but not limited to the following: perimeter security measures from land and sea to limit access to the port to only those

authorized to be there and to detect break-ins; methods to ensure that only authorized individuals (for example, employees of the port itself, including dock workers and administrative staff, and nonport employees, such as truck drivers and customers officials) can access the port area; detection systems for drugs and weapons or explosives; identification of areas requiring specific security measures, including connections to utilities (electricity, gas, water supply), infrastructure including equipment, secure storage areas, and bonded warehouses (where items on which excise duty must be paid are stored); and securing any areas where hazardous materials are stored.

Once an assessment has been conducted, the port security officer develops and regularly updates a security plan, and ensures that all employees are aware of what they need to do in the event of it being activated. It includes which measures are to be taken to ensure that cargo, containers, essential equipment, port buildings, and infrastructure are not tampered with in any way.

In addition to the ISPS Code, joint work was undertaken between the International Labor Organization (ILO) and the IMO to develop an ILO/IMO Code of Practice on Security in Ports. Although not legally binding, this code provides guidance to all parties involved in port security, including governments, port employees, and workers, to reduce the risk to ports from any potential security threat. It also provides guidance on how to carry out a port security assessment and develop a port security plan.

U.S. Container Security Initiative

In addition to the measures put in place by the IMO internationally, the United States introduced a Container Security Initiative (CSI) in 2002. That initiative aimed to develop a system of prescreening of shipping containers destined for the United States while still in a foreign port. Under this system, U.S. Customs and Border Protection (CBP) works with foreign customs services to inspect high-risk containers and, at the time of this writing, 58 foreign ports were participating in the CSI, covering 85 percent of all container traffic bound for the United States.

The three main elements of the CSI are identifying high-risk containers that pose a potential risk from terrorists, screening them before they depart

for the United States, and using technology to conduct that screening without causing any delays in the transport of the cargo.

Identification of high-risk containers is done using the advanced analysis of information contained in cargo manifests or bills of lading, which must be submitted to the CBP at least 24 hours before the container is loaded on a ship destined for the United States. The information provided is screened using an Automated Targeting System, which identifies shipping containers that pose the highest risk based on their contents and targets them for inspection. A benefit of this system is that containers with no or very low risk, particularly those where some form of electronic or physical seal is in place to prevent the contents from being tampered with, can be transported much more rapidly.

Once a container has been identified as being high risk, it is inspected in port (or potentially even before it arrives in the port, if information is provided at an early stage in its transportation). In many ports, particularly those with limited access to technology, containers are inspected manually. This can involve all of its contents being removed and examined by hand, and may even include manufactured goods being disassembled to check that nothing is being smuggled within them. This also may result in considerable delays, particularly if the container is filled with different types of goods from a number of different sources, and where there is extensive paperwork associated with its contents. In addition, canine teams may be used to search for drugs or other substances, or stowaways hidden within a container.

In order to speed up the process in CSI ports, a number of nonintrusive methods are available to screen a container, including X-ray or gamma-ray scanners to generate an image of the contents and identify whether any additional searches are needed. Radiation detection devices also can be used. This technology means that far fewer containers will need manual inspection, and so ships can be loaded more quickly, speeding up the transport of goods from CSI ports to the U.S. mainland.

In order to further assist with the security of containers, geographic information system tracking can be used to geographically locate containers and provide an up-to-date location at any point in the container's journey. Security seals can be added to containers after they have been cleared

by inspection; these are designed to ensure that the container and its contents remain untouched until they arrive at their final destination.

Inspections of Ships in Port

The second type of inspections conducted in ports are intended to ensure that ships entering a port are in compliance with international conventions and any regional measures (for example, European Union directives) or national or state-level legislation. These inspections are carried out under a system of Port State Control, where foreign-flagged ships (sailing under the flag of a country different from that of the port) can be inspected to ensure that they meet required standards and that they, and their crews, are safe to sail on to their next destination.

Ship inspections are conducted under a network of regional Memoranda of Understanding (MOU) on Port State Control regimes around the globe. Nine MOUs were established globally between 1982 and 2005, and they cover all the world's oceans. The first of these was the Paris MOU, which covers Europe and the North Atlantic, and the most recent is the Riyadh MOU, which covers the Arabian Gulf region.

While the United States is not a signatory to any of the MOU regimes, it is an observer to the Black Sea and Tokyo MOUs, and port state control activities and inspections are conducted by the U.S. Coast Guard. U.S. inspections cover compliance with environmental, safety, and security measures, as well as the adequate identification of ships' crews and tracking of ships at sea.

Each MOU regime works with the IMO to ensure that ships entering member-state ports are in compliance with a range of international conventions, and also any relevant regional agreements, treaties, or regulations. For example, European Union member states that are signatories to one or more of the Black Sea, Paris, or Mediterranean MOUs may also be required to ensure that ships adhere to the requirements of any relevant EU directives, wherever an agreement has been reached to include such measures in the ship inspections.

Inspection Procedures

Inspections of ships in ports are conducted by Port State Control Officers (PSCOs) once a ship has been identified as needing inspection. Inspection



U.S. Customs and Border Protection (CBP) officers board a ship to begin a port inspection in May 2004. CBP works with foreign customs services in 58 foreign ports to prescreen high-risk containers, a system that covers 85 percent of all container traffic bound for the United States.

triggers include a port being informed that deficiencies have been previously identified on the ship, that a pilot bringing a ship into port has identified problems relating to safe navigation of the ship, that the ship is carrying dangerous or polluting goods on board, that it has failed to supply the port with full details, or the ship has not visited a port in an MOU member state for over a year. It can also occur if the documents held by a ship are not from a recognized authority.

An initial inspection of a ship includes checks on the overall condition of the ship and its hygiene. The PSCO checks for areas of corrosion and cracks on the vessels hull, for example, or whether

regular safety drills have been carried out. The initial inspection covers the bridge, accommodations, galley, decks, cargo holds, and engine room to make sure they meet acceptable standards, that any problems identified during a previous inspection have been corrected, and that all the relevant standards are being met. It also checks that all the relevant documentation is available and up-to-date. This covers areas including safety certificates for radio or safety equipment, certificates relating to SOLAS, and medical certificates for the ship's crew.

If there are any deficiencies or problems identified during the initial inspection, or if all the required certificates and documentation are not available to the PSCO, a more detailed inspection will be conducted. That inspection will cover not only those areas where a deficiency has been identified but also a random selection from a list of 14 risk areas on board. Those risk areas include the structural condition of the ship, that it is water- and weather-tight, that all the emergency systems are in working order, that radio communications are working correctly, and that life-saving appliances, such as lifeboats, life rafts and life belts, are well maintained and accessible.

An expanded inspection may also be conducted if the PSCO considers this appropriate, and all 14 risk areas are included in this inspection. If a ship fails a port inspection, it may be permitted to sail to another port if the deficiencies are minor or if repairs cannot be carried out in the current port. However, for major deficiencies, the ship may be detained in port and prevented from leaving until all work to fix identified problems has been completed.

International Conventions Covered by MOU

There are a number of international conventions and their protocols (amendments at a later date) covered by MOU port inspections, and against which ships can be inspected for compliance. The Paris MOU inspects against 10 conventions, nine of which are administered by the IMO and one of which is a convention of the ILO. This is the Merchant Shipping (Minimum Standards) Convention of 1976 and its Protocol of 1996, which covers areas including the setting of a minimum age for seafarers, requirements for crew accommodation, and measures relating to the prevention of accidents.

Of the remaining nine conventions for inspection under the Paris MOU, one is the SOLAS convention discussed previously, which covers safety

aspects onboard ship, including fire safety, life-saving equipment, carriage of cargoes or dangerous goods, and any measures to ensure the safety of a ship both at sea and in port.

Another convention with measures directly impacting both ships and ports is the International Convention on the Prevention of Pollution from Ships 1973, and its Protocol of 1978. This sets out requirements for ships regarding where and how much of different categories of wastes can be discharged at sea. It covers oil, noxious liquids, hazardous substances in packaged form, sewage, garbage, and air pollution from ships. It also includes measures requiring ports to provide reception facilities for certain types of waste. This convention aims to reduce pollution entering the marine environment and includes measures relating to ship inspections in ports.

Other examples of IMO conventions covered within inspections include the International Convention on Load Lines 1966 and its Protocol of 1988, and the International Convention on Standards of Training, Certification and Watch-keeping for Seafarers (STCW) 1978. Load lines were introduced as a measure to prevent ships from being overloaded in port, using a system known as reserve buoyancy that identifies how low a vessel can ride when fully loaded and remain watertight, depending on the region and water type (for example, freshwater or seawater, summer or winter) where it sails. The STCW covers minimum standards for various members of a ship's crew and also for different types of ships. PSC inspections are required to check that certificates for all crew members are up-to-date, and that they have received the appropriate training for their rank and the type of ship they are working on.

Ensuring compliance with the various conventions, as well as any regional agreements, is the responsibility of the specific MOU regime. Those regimes also set out a minimum number of ships to be inspected in its ports annually, based on a percentage of the number visiting. Ships visiting ports in the Tokyo MOU region are far more likely to be inspected because it has a target rate of 80 percent of both foreign-flagged and MOU-member-flagged ships to be inspected annually. Under the Paris MOU regime, the target is 25 percent, while the Indian Ocean and Riyadh MOUs set a target of 10 percent; the remainder have targets between 10

percent and 20 percent. In other words, the number of inspections carried out in the Asia-Pacific region is much higher than anywhere else in the world.

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See Also: Container Terminals; Containerization/ Container Shipping; Freight Transport, Security Issues; Harbor and Port Security; Ships; Water Pollution; World Container Ports.

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Privately Owned Vehicles

Throughout the developed world, automobile trips account for about 70 percent of all trips not made on foot; in the United States, they are responsible for nearly 90 percent, as well as virtually all nonwork travel (more than half of public transit use being for work/commuting purposes). After mortgage or rent, transportation is the largest expense in the average American household, even exceeding education, despite the ballooning costs of tuition. Even today, when American manufacturing has been in steady decline for many years, car manufacturing and services account for 4.5 percent of U.S. employment.

The United States has one of the highest rates of automobile ownership in the world. According to the World Bank, which measures motor vehicle ownership in several ways, the United States has the third-highest ratio of motor vehicle ownership per thousand people (a statistic that includes buses and commercial and freight motor road vehicles in addition to automobiles, SUVs, vans, and pickup trucks), exceeded only by the small wealthy nations of San Marino and Monaco.

This rating is inflated somewhat by the size of the commercial trucking industry in the United States, but the World Bank also measures private car ownership, and the United States ranks among the highest, with 423 cars per 1,000 people in 2010 (down from 450 in 2008). While historically the United States has ranked among the countries highest in car ownership, in recent years more European countries have begun to overtake it.

The United States is one of the largest countries in the world by area, which is a factor both in its

unusually large fleet of freight vehicles and its relative lack of comprehensive public transportation for so much of the population. (The cities with the smallest percentages of car-owning households are predominantly northeastern urban centers with enough population density to make driving less practical than public transit—the New York metropolitan area accounts for the three smallest, followed by Washington, D.C., and Hartford.) Given its large population and its large number of vehicles per capita, it is no surprise that the United States has the largest fleet of passenger vehicles in the world, and has for many years. Historically, it has also led the world in annual automobile sales, though this changed in 2011.

That said, in the wake of the 2008 financial crisis and findings of the 2010 U.S. Census, many suggested that "peak driving" had been reached, and after steadily climbing for decades (even in the face of active attempts to reduce car dependence), car ownership and use would enter a decline. A report from Transportation Research Institute researcher Michael Sivak found that even prior to the 2008 economic crisis, the ratios of vehicles per person, per licensed driver, and per household had hit their maximums, and had been declining since, just as the absolute number of vehicles had begun declining after the recession.

Not all of the factors are clear, though Sivak notes that the number of telecommuters increased by a third from 2000 to 2013, and the number of teenagers obtaining their driver's license at later ages had increased. Declines have also been seen in other previous leaders in driving, including France and the United Kingdom, both early adopters of car culture.

However, even as car ownership and driving decrease in the United States, they are increasing significantly worldwide, as developing nations grow their middle classes. In 2011, China overtook the United States in automobile sales, and 2012 and 2013 each set new highs in global automobile production. Because the transportation infrastructure has developed more quickly in developing nations due to improvements in technology, efficiency, and the industries supporting such infrastructure, car ownership has been adopted faster; and developing nations typically have a higher rate of car ownership than the developed nations, including the United States, had achieved at equivalent levels of income

or gross domestic product. Of course, massive car ownership expansion was also a major factor in China's 2010 11-day traffic jam.

National Household Travel Survey

The most recent National Household Travel Survey (NHTS) was administered in 2009, too long ago to reflect or address these trends. The NHTS is administered by the Federal Highway Administration for the U.S. Department of Transportation, at irregular intervals, having previously been administered in 2001 and preceded by five similar surveys from 1969 to 1995. Like the census, the NHTS is a comprehensive survey of the United States, but focused on travel: every trip made in a 24-hour period by each surveyed household, whether walking to the mailbox or driving to a grandmother's house.

One of the only other countries that tracks as many travel statistics as the United States is the United Kingdom (UK), which has found that car usage peaked in the 2000s and that most statistics reflecting drivership and car usage have either plateaued or declined in the 2010s. Some of the decline in car usage is simply a fact of changing demographics.

The first generation for whom driving was default behavior and car ownership an assumed eventuality has now retired; the number of retired drivers continues to rise, and the baby boom generation's unusually large size has increased the share of retirees in the population. Thus, even preserving the status quo of behavior patterns—upon retirement, many drive less often because they are no longer driving to work—would result in a decline of vehicle miles per licensed driver.

Another trend seen both in the United States and in Britain, as well as in France, Norway, South Korea, and Germany, is young people waiting longer to get their licenses than they had in the past. In 2010, only 28 percent of 16 year olds had licenses, compared to 46 percent in 1983; 46 percent of 17 year-olds, down from 69 percent; 61 percent of 18 year olds, down from 80 percent; 70 percent of 19 year olds, down from 87 percent; and 81 percent of 20 to 24 year olds, down from 92 percent.

Americans under 35 in general have proven to be far less interested in driving than previous generations, and several studies have suggested various reasons to explain this, all of which may



Private cars, taxicabs, and a bus vie for position in heavy traffic near a railway station in Xiamen, Fujian Province, China. China has surpassed the United States in automobile sales and is experiencing rapid growth in private automobile ownership.

be contributing factors: young people are more socially and environmentally conscious, which makes them less enthusiastic about driving; they are enthusiastic supporters of public transportation, which meets many of their travel needs (according to a Frontier Group study, public transportation usage doubled from 2001 to 2009 among Americans aged 16 to 34 in households with incomes over \$70,000); they are less likely to have children, freeing them from many of the errands that cars make easier; in recent years, larger numbers of them have moved back home with their parents, who may perform many of the errands a car requires; and they are the generation most at home online, which some say has replaced

a portion of the car trips other drivers perform for social or recreational purposes.

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See Also: Automobile Travel Patterns; Driver Licensing Rates; Travel by Households; Travel by Persons; Travel Choice; Vehicle Ownership Models.

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Privatization of Public Transit

Privatization is the transfer of publicly owned assets or publicly operated services to private ownership or operation. Privatization of public transit systems takes many forms. Moves to privatize public transit are usually motivated by a combination of cost pressures on governments and a desire for improved transit services. At the same time, though, the operation of public transit requires legal and regulatory powers that only governments can provide. There is also political pressure for transit operators to provide services in circumstances that do not generate commercial returns. Not surprisingly, therefore, privatization is almost always a controversial and contested process.

Historical Context

Prolonged worldwide economic stagnation in the 1970s and 1980s diminished the capacity of

governments in modern industrialized countries to fund many projects. Privatization became a significant part of a reform agenda to shift control and ownership of productive resources to private-sector entities. At the same time, those activities left in state control and responsibility were subject to marketization reforms. These involved the competitive supply of services by the private sector, on the one hand, and the expectation that government enterprises would mimic private corporations, at least as far as management practices were concerned, on the other.

The United Kingdom became a worldwide leader in privatization following the election of Margaret Thatcher's Conservative Party government in 1979. Privatization became widespread shortly afterward across Europe and in the United States, especially, under the leadership of President Ronald Reagan (1980–88). The collapse of communism in eastern Europe in the late 1980s and early 1990s saw the onset of privatization measures in that region. This was part of the widespread dismantling of systems of state-planned and -controlled development, as well as the sell-off of state-owned enterprises (SOEs).

Concerted privatization programs in developing countries also date from the 1980s and 1990s. The initial impetus for the sell-off of SOEs came from rising public indebtedness in a number of Latin American, east Asian, and sub-Saharan African nations in the mid- and late 1980s. In these regions, privatization was a central part of the International Monetary Fund's (IMF) structural adjustment programs for developing nations in need of assistance.

Types of Privatization

It is possible to identify three general types of privatization. The most common form is the sale of SOEs into private ownership. However, there are considerable difficulties when it comes to the outright sale of public transit systems. This is because a public transit system is usually a bundle of integrated assets acquired as the system developed over time, usually in the hands of a government-owned utility. In the case of a rail or metro service, for example, this bundle of assets might include the rolling stock; the rail and signaling assets; stations and associated amenities; fare-collection systems; operational, administrative, and management teams; integrated retail

spaces; parking spaces; unused land and air spaces that might be valued for commercial property development; the property rights that guarantee passage across a city; and other infrastructure assets, such as information technology (IT) cabling or water pipes, which often co-use a rail passageway.

Some of these assets can be dismantled quite easily to be sold to commercial operators or developers. For example, car parks and idle land around railway stations could be sold to a parking lot operator. Even a fare-collection service could be run by an external company, in a similar way to how large retailers outsource their credit and cash register systems to specialist financial-services firms.

Unbundling other assets is much more difficult. One strength of government-owned utilities is the way they enable public transit services to be operated in ways that exploit their natural monopoly status for public benefit. A natural monopoly occurs when it makes no sense for a product or service to be supplied by more than a single provider. It would be inefficient, for example, to have rival metro systems attempting to provide blanket coverage across a single metropolitan region. One well-functioning metro system is quite enough.

Privatizing natural monopolies, then, comes up against the problem of how to introduce competition and develop markets without sacrificing the benefits that flow from having a single large, integrated public provider—whether it be water, energy, telecommunications, school education, or public transport. Can a group of rail companies, for example, compete for commuters on a single rail surface without the loss of coordinated timetables and integrated services that are intrinsic to a well-functioning rail or metro system? Can railway stations be separately owned and still genuinely compete for users? Can signaling services be based on the same private-sector market disciplines that apply to, say, the supply of groceries or clothes?

Privatization also refers to a shift in responsibility for the provision of basic and community services from the public sector to commercial, for-profit enterprises. A common expectation that developed around the world during the 20th century was that the function of a nation is to organize the provision of basic services for its citizens. Many of these services fall into a category called public goods, which are goods or services that are created through universal provision. Public transit

services came to be seen as a public good because the personal and private provision of, say, a light-rail service today makes no sense. A viable suburban light-rail service can only come into existence as a public good, just as an apple or a haircut can only ever belong to the private-consumption category.

Yet, many governments have privatized the provision of public goods, including transit systems, but they have done so in contractual ways that mandate conditions that more or less correspond to public-goods expectations. Sometimes this type of privatization is accompanied by a subsidy or concession to ensure access by some users on a noncommercial basis, typically based on equity or need criteria.

At the edges of the public transit system, there are also many services that are readily contracted out to private providers. These include simple things such as retail spaces on passenger concourses, cleaning and maintenance contracts, payroll and other administrative services, and so on.

Privatization also refers to a shift in regulatory roles away from centralized determination by governments and government agencies. Examples of the shift away from state-led regulatory systems include the following: the adoption of regulatory standards developed by supra-national agencies, such as the International Organization for Standards (ISO); industry-based regulatory bodies, sometimes called self-regulation systems; shifts away from centralized, state-administered labor regulations to work arrangements based on employer–employee contractual relations; and the replacement of authorities with responsibility for the conduct of social and sporting events with bodies drawn from the voluntary and community sectors.

The shifts in regulatory responsibility away from the state, or the abandonment of regulations altogether, are often described by reformers as either deregulation or market liberalization policies.

Unbundling

Unbundling confronts the problem of the privatization of public services when these have been sourced from integrated public utilities. As mentioned, there is a wide range of valuable assets and commercial rights that utilities are able to assemble. Dismantling public utilities, including those involved in transit services, has created two

major problems. The first is the problem of how to introduce market competition in a sector dominated by natural monopolies. The second is how to maintain the benefits of an integrated operational system when the parts of that system are sold off or contracted out to private, for-profit owners and operators.

Solving these problems involves the introduction of two different types of marketization processes. One is competition within the market. In the case of public transit systems, such as the UK interurban rail system, competition for the market involves bidding between rival rail operators for designated rail services for limited periods, but also the opportunity for the introduction of new services that might attract additional patronage and, therefore, money-making opportunities.

Of course, both competition and innovation require the use of common railway thoroughfares. Hence, genuine market competition is compromised by the need to maintain orderly timetables and uncongested rail corridors. A role for governments as strong market regulators and contracts/concessions negotiators becomes essential, then, as ingredients to facilitate competition among transit operators.

The second solution is competition for the market. In this case, governments sell monopoly rights to those parts of the transit system for which it makes no sense to have competing providers (for example, for stations, signals, and tracks). These rights sales are seen to have market discipline because they are based on competitive bidding, and because they require scrutiny by a regulator with regard to quality of services, pricing, and rates of return on capital. In this sense, the private producer is seen to be behaving as if it were in a competitive market situation.

Effects of Privatization

A successful privatization program would see governments relieved of the burden to supply expensive infrastructure capital, and consumers enjoying better transit services at cheaper rates. Unfortunately, it is difficult to find examples where governments and consumers agree that the privatization process has been an unmitigated success. Inevitably, because privatization introduces conflict between the desire of a private firm to maximize revenue and profits, and the desire of

passengers to enjoy ever-improving services at lower costs, there will never be full agreement on the benefits of privatization.

Moreover, just as state-run utilities often fail to achieve their ideal of a universal provision of quality public services, so, too, do privatized transit systems suffer from failure on their terms, a situation called “market failure.” Market failure can be very dramatic; for example, when a major transit operator fails financially, ceasing operations and thereby leaving vast tracts of an urban area without commuter-train services, the government has no easy way of introducing an alternate supplier.

Although there is widespread evidence that the privatization of public transit systems has led to more efficient service provision and reduced cost pressures on governments, the commercial viability of privatization often comes at the expense of the end user, who may have to endure crowded commuter services, rising fares, and the loss of conveniences such as transit that still runs late at night when customer patronage levels are low.

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See Also: Deregulation; Economic Development; Fiscal Politics; Transit Finance; Transit Industry, Economics of; Transportation, Economics of; Transportation Planning and Politics.

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Public Participation in Transportation Planning

Public participation includes stakeholders in making and implementing public policies and programs of government agencies, political leaders, or nonprofit organizations. It has become a fundamental feature of governance in a wide range of public issues.

Public participation plays an important role in a variety of transportation-related activities, including planning, formal policy making, program and service design, and evaluation. Notably, the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 imposed new requirements for public involvement in the planning process in the United States. Public participation can be designed in a variety of ways, guided by a few key questions about its purpose, the stakeholders, and the evaluation measures. Other common terms for public participation include public engagement, citizen participation, civic engagement, collaborative governance, stakeholder involvement, and inclusion and representation in democracy.

Public participation in transportation planning takes a range of forms, including simply informing stakeholders of decisions that are being made, soliciting and using their input on programs or policies under consideration, or collaborating with them to identify and address problems. Transportation policy stakeholders are those with a stake in the decision, which may include the general public and/or groups with specific interests, because of their geographic location, transportation needs, or related concerns.

There is no formula for doing public participation well. Like transportation services or infrastructure, public participation needs to be designed for its particular context. Regardless of the specific strategy, policy makers and planners must consider several critical factors in designing and managing successful public participation: clarifying what parts of the decision are open for discussion and change, ensuring public trust in the process, working with expert and other perspectives, and being accessible to all stakeholders.

Although public participation requires resources such as skill, time, and money, it generates numerous advantages. Citizen participants contribute

new information, different ways of seeing an issue, and motivation to address problems. Public participation can also result in more equitable distribution of limited public resources. The public tends to have more informed involvement and a higher level of interest when given opportunities to identify priorities, shape decision-making parameters, or influence policy outcomes.

Participatory decision making generates better buy-in and can limit delays, mistakes, and lawsuits during project and policy implementation. Stakeholders are more likely to accept a decision reached in a participatory manner, even when it is not their individually preferred outcome, because they believe it was produced in a fair manner. In fact, inclusive participation can create relationships of trust, knowledge of and interest in transportation issues, and improved communication among parties that are resources for policy implementation and for addressing new or different problems.

Designing Public Participation

There is no one-size-fits-all, ideal approach to public participation but rather myriad techniques and frameworks. Choosing among these approaches is both challenging and consequential. The forms of public participation influence the quality of policy outcomes and affect the capacity to address current and future issues. Guided by a few key questions about its purpose, the role of stakeholders, the methods for organizing the effort, and the evaluation measures, it can be done well.

Transportation planners should begin participation efforts by considering the purposes of the public engagement effort, including what is at stake and what the desired outcomes are. Deciding what is at stake includes evaluating which parts of a decision are available for stakeholder participation. For example, some aspects of transportation planning are dictated by legal requirements, best left to engineers or other experts in a particular technical field, or unable to be decided by a single jurisdiction and its constituents.

In terms of desired outcomes, a particular effort may involve more than one purpose, such as meeting regulatory requirements for participation, being sure that stakeholders are informed about a proposed action, exploring the nature of an emerging problem, improving the quality of a proposed project or policy through stakeholder

feedback, generating ideas for a new initiative, or building relationships for implementation or future problem-solving.

Once they have identified desired outcomes and the appropriate scope of the public's participation, policy makers decide which techniques to use and how to communicate with stakeholders about what to expect and how to participate. An accessible and popular tool to help with this is the Spectrum of Public Participation created by the International Association for Public Participation (IAP2). The Spectrum identifies differing levels of public engagement depending upon the goals, resources, impact, and time frame for the decision. It clarifies that no one approach is better than another, but that goals, communication with stakeholders, and techniques must be aligned. Being very clear about the purpose and scope of public participation helps build trust and legitimacy for the participation process and its outcomes.

Existing Approaches to Public Participation

There are many methods for involving the public in transportation planning, from a public hearing before the elected or appointed body making a decision to more inclusive approaches in which stakeholders are involved in identifying problems and coproducing solutions. In the past decade, transportation agencies around the world have involved the public in a number of ways:

Advisory boards. Advisory boards are comprised of a group of stakeholders recruited to provide guidance on a policy area or project. Members may be selected by elected officials, commissions, public administrators, and project managers. They may be intended to represent the public at large, to bring a particular perspective (for example, an advisory committee on disabled transit riders), or to incorporate a range of stakeholder groups. Advisory groups may meet regularly, as needed, or for a limited term to address a particular question. They do not generally have policy-making authority, and their influence on policy agendas and outcomes is mixed.

Project review teams. These teams help transportation professionals to evaluate possible transportation projects. They may rank projects from a pool of proposals or simply share comments and raise

questions for transportation professionals to incorporate into their reviews.

Collaborative performance measurement. Collaborative performance measurement brings together service providers with stakeholders to evaluate service or project performance. It can be used to evaluate performance problems and to identify and address situations where different parties have divergent goals and expectations for a service.

Focus groups and workshops. Focus groups and workshops help professional staff or political leaders to gain additional perspectives on a problem through consultation with interested stakeholders or with members of the general public. Participants may be given a set of questions or issues to discuss or be invited to comment on a policy. The consultations can be designed for a variety of purposes, such as gaining information about issues of greatest concern to constituents, involving a program's users in its performance evaluation, or improving a project so that it is more politically feasible or more responsive to client needs.

Deliberative polls. Deliberative polls are a trademarked method for identifying the questions that the general public would have about a policy issue if they became better informed and discussed them in depth with people with differing viewpoints. These polls can lead to better communication strategies about transportation policies. Participants are randomly selected, prepared with a briefing packet, and invited to attend a deliberative forum in which small, facilitated groups discuss the issue and decide together which questions about the policy they would like to pose to experts and decision makers. Organizers later relay their questions to the media, policy makers, or experts.

Planning charrettes. Planning charrettes are collaborative design exercises that allow stakeholders to directly experience, manipulate, and play with design components through games, simulations, maps, field trips, or other objects or experiences. They typically incorporate a variety of media, such as 3-D models, photography, and rendered landscape images. The models can be shaped to communicate which parts of a project are fixed (for example, lane width) and which are flexible. Planning charrettes

can help the public to understand transportation options and communicate their questions and suggestions to engineers and planners. Using mixed media may be associated with greater public satisfaction with the outcomes.

Structured public involvement. Structured public involvement (SPI) involves the public in every decision phase, from defining the nature of the transportation problem to creating the scope for the policy to setting design goals and refining the options together. Recommended as a best practice for involving the public in design decisions, it occurs through focused explorations and strategizing about separate pieces of the policy. Piece by piece, participants suggest ideas and make modifications concerning each piece until there is general agreement, and then integrate it with other pieces of the policy. When convening these processes, transportation professionals must be responsive to multiple perspectives, help nonexpert participants understand the technical aspects of the policies, be competent facilitators, and be willing to cede some of their decision-making power.

Interactive optimization tools. Interactive optimization tools involve the public in manipulating a fixed set of resources to choose among a menu of policy options. In some designs, users can move back and forth between setting performance criteria (for example, persons moved per hour) or resource parameters (for example, a total budget) and the menu of projects, so that they can see the interplay between them. Frequently they use an online platform.

Participatory action research. Participatory action research involves researchers working with interested parties to perform research driven by their questions and concerns. Activities include gathering and analyzing data, identifying problems to address, or generating and evaluating policies. Developing these community-led initiatives requires technical assistance. Some researchers provide pro bono support, or sometimes transportation agencies provide consulting support. Generally, institutional actors must have buy-in in order for the resident-driven contributions to be taken seriously.

Geographic analysis of public comments. This analysis uses geographic information systems (GIS) to

identify geographically based needs for additional outreach about transportation decisions and to identify geographically specific patterns of feedback about projects.

Key Challenges

Several challenges commonly arise in designing and managing successful public involvement in transportation policy making: the legitimacy of and trust in the engagement process, incorporating expert and other perspectives in technically complex transportation decisions, and engaging diverse stakeholders.

Trust and Legitimacy Issues in Engagement

One complaint commonly raised by the public about engagement processes is that their involvement does not seem to influence decisions. This causes resentment when stakeholders are invited to participate, yet there is very little that can be changed in the policies or projects that have already been put together. Sometimes conflict occurs when sponsors have not communicated what the participation is for, and participants arrive with different expectations, for example, if a public agency is simply informing the public of a decision and the public arrives wanting to change it.

If their different expectations are not ironed out, public processes can easily become mired in conflicts about their legitimacy, sometimes leading to accusations that they are perfunctory or manipulative. The IAP2 Spectrum suggests good ways to communicate with the public about the engagement's purpose, for example, "We will keep you informed" versus "We will implement what you decide."

Timing is an important part of accomplishing and communicating the goals for engagement. Consulting with stakeholders early in policy development allows policy makers to better shape the scope, priorities, or performance measures of the work. A two-way information exchange is most needed in the planning and design phases, so that stakeholders can weigh in on the most suitable goals and design of a project. A one-way process is more appropriate for the construction stage of a project, when the focus should be on disseminating good information to the public about road closures or the construction sequence.

Transportation policy makers and planners must also communicate what can and cannot be

decided through the engagement process. Many transportation parameters are mandated by federal or state legislation, which may limit the power of local actors or the public to influence the outcome of a project. Because transportation initiatives take place in a multi-jurisdictional environment, it can be difficult for community members to understand which agencies are responsible for which actions or to engage with the many agencies involved. Online methods, which are consistent with the rise of e-government and Web 2.0 government across many policy sectors, provide a promising platform for addressing regional-scale problems. They can connect geographically dispersed people who are affected by large-scale transportation policies but who may be unable to attend meetings because of the distance.

Engaging Expert and Other Perspectives

A prominent challenge in transportation planning is how to engage both experts and everyday stakeholders in technically complex decisions. Administrators may worry that giving the public influence over decisions traditionally left to those with engineering or other specialized expertise will produce choices that do not adequately consider safety, equity, efficiency, environmental protection, and political feasibility. They may also be concerned about limiting their managerial discretion to act decisively as needs arise, or about the resistance that well-organized groups may mount when they have more complete information about projects. Making issues and choices understandable to the public so that they can be informed participants is another challenge.

The public's increasing involvement in transportation decision making also offers advantages that can improve technical decision making. Non-experts bring lived experience and empathetic understanding that can produce new data and new understandings of problems. Without this knowledge, experts may undervalue considerations that should enter into their decision-making process. In addition, when a transportation agency limits information about expert-decision parameters, it can fuel a perception that the agency is withholding information or changing the rules midstream, compromising the credibility of its decisions.

Well-designed public participation can help address these challenges and provide an avenue for

valuable public contributions. Charrette and online optimization tools, for example, do not require people to be able to read engineering plans or technical documents in order to understand a policy and provide meaningful input. Such techniques can bring varying perspectives to bear on evaluating policy options.

Enhancing Diversity and Equity

Across all sectors, including transportation policy making, diversity and equity in access to public engagement are particularly persistent concerns. In general, individuals of higher socioeconomic status are more likely to have the time, money, civic engagement skills, or Internet access to participate, and those with greater individual and collective social capital are more engaged or exert more influence. As a result, the individuals or organizations who participate in engagement efforts may not be representative of the opinions and knowledge of the public at large.

In transportation, low-income communities may have a disproportionately high interest in transit policy and planning discussions, such as those related to public transit services. To reach them, alternatives to the traditional public hearing—such as telephone surveys or gathering input at transit stations and other locations convenient to these constituents—may be necessary to gather their input. Purposeful efforts to provide outreach in multiple languages and to provide translators are important for reaching constituents who are not comfortable communicating in English. Public and nonprofit organizations frequently consider religious institutions to be an effective venue for reaching nonwhite constituents about public issues, but such a location should be adopted with care so that diverse stakeholders feel welcome through one means or another.

Another challenge is enlisting a sufficient level of diversity without classifying constituents into stakeholder groups that do not capture their full range of interests. The concept of the “public” is complicated and multifaceted in transportation. There are, for example, strong differences in the interests and preferred modes for public engagement of the “freight community” and the “passenger community” in infrastructure planning.

Similarly, bicyclists are not a homogenous group, and misunderstandings and controversies may

arise if recreational riders, those who commute and occupy a lane like other vehicles, and long-distance riders are all lumped together as a single interest group. Transportation professionals must also take care not to orient too intensively toward engaging organized special-interest groups, because that may exclude the general public and raise the risk that a vocal, and perhaps unrepresentative, minority could have undue influence on policy making.

Evaluating Public Engagement

The final step in the process is evaluating the public-engagement effort. Evaluation allows policy makers to learn from the implementation, so that they can enhance the current engagement effort and build long-term institutional capacity. While evaluation can occur when a process is already under way or over, it is important to include it from the beginning of the design process. What are the desired outcomes, and how will they be measured? The typical measure—the number of participants, and perhaps some demographic information about them—is not adequate for meeting and evaluating most of the goals of public participation.

Methods for evaluating public engagement are not well established, but some resources do offer a starting point. The standards introduced by ISTEA for public involvement provide a common reference point across the transportation sector in the United States.

The ISTEA standards are that engagement be early and proactive, that timely information be provided to the public, that there is proof of explicit consideration of the public input, and that the input of traditionally underserved communities has been sought and included. Other measurements could include the degree of learning achieved through the process, by both participants and conveners; changes in capacity to implement policies, as observed through changes in conflict or agreement among stakeholders; and the overall quality of the final policy decisions in terms of their economic efficiency, safety, environmental impact, and political viability.

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See Also: Construction Management, Public Relations and; Transit Planning, International; Transportation

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Public Transit Employees and Labor Issues

Public transit in the United States is a shared passenger transport service that is available for use by the general public. Forms of public transit include buses, trolleys, trams, trains, rapid transit (such as subways), and ferries. Public transit between cities and states includes airlines, intercity rail, coach bus services, and high-speed rail networks. No matter the type of vehicle or infrastructure within which the vehicle must travel, public transit employees face similar working conditions and stresses on the job.

Historically, some public transit employees have also faced forms of discrimination. To improve working conditions and compensation, and reduce discrimination in the industry, unions have formed to protect the interests of public transit employees.

At the same time, pay and benefit inequities exist between public transit employees who work for the city, county, or state and those employed by private companies, who, without unions to bargain on their behalf, may be paid less and receive fewer benefits.

Therefore, to cut costs, some governments are looking toward private, nonunionized companies to staff public transit services. While the long-term effects of such practices remain unknown, transit unions and other advocacy groups are committed to the idea that properly compensated, trained, and protected public transit employees provide better customer service and safer travel.

Public Transit Employee Categorization

The American Public Transit Association (APTA) identifies all public transit employees as operating employees, or anyone engaged in the operation of the transit system. APTA classifies operating employees in four categories. General administration employees manage and administer activities such as transit system development, system development, customer services, promotions, market research, injury and damage claims, safety, personnel administration, finance and accounting, and space management. Nonvehicle maintenance employees engage in support to vehicle maintenance employees, the third category, which is comprised of those who inspect, maintain, and repair vehicles. Last but not least, vehicle operations employees are the drivers, pilots, train conductors, ferry captains, fare collectors, and those engaged in system security activities. They make up the vast majority of operating employees in the United States.

Commuters in urban areas, as well as long-distance travelers, depend heavily on vehicle operations employees and vehicle maintenance employees to get them to their destinations safely and on time. Public transit also employs capital employees—those whose labor-hour cost is reimbursed under a capital grant, separate from the public transit employee budget.

Working Conditions

The public transit industry has particular employment issues that often bring the nature of the work and workers' rights into conflict. First, most vehicle operations employees interact with passengers.

Time-sensitive travel increases stress levels for both drivers and passengers, and customer-operator interactions can lead to conflict.

Second, vehicle operations employees—bus drivers, in particular—often do not have set times or places to take breaks. Transit agencies attempt to deal with this issue either by identifying the layover period as a break or by awarding drivers a lunch break once they reach their terminal destination. Vehicle operations employees also do not have the freedom to take bathroom breaks as frequently as they may require.

All public transit employees—particularly vehicle operations employees—face the phenomenon of split shifts. Most transit systems provide more services during peak commuting hours than at other times. For vehicle operations employees who work during peak hours, there may be no work in the middle of the day. Such drivers could work three to five hours in the morning, have anywhere from a one- to three-hour break, then work three to five hours in the afternoon. The “break” is unpaid, and the driver is not free to go home because their work day has not ended.

According to the Bureau of Labor Statistics, the transportation industry had the greatest number of days missed from work due to injury and the second-greatest number of fatal accidents. Many injuries result from long hours spent in uncomfortable seats, as well as assaults on operators by passengers. Absenteeism also continues to be a major problem in the public transit industry. Job stress and burnout cause many transit operators to abuse alcohol or drugs, which puts them at risk for job termination.

History

In the 19th century, stagecoaches served as a common mode of transportation for long-distance travel. Four to nine passengers could sit in the coach, depending on the model, and the coach driver would sit outside the cab to steer the horses. Coach drivers worked long hours under extreme weather conditions, and in the days when they had to cross the American frontier, often had to take the law into their own hands if approached by bandits or unfriendly Native American tribes. Most frequently, however, the stagecoach driver had to monitor passenger behavior and evict drunk, unruly passengers from the coach.

While horses were entitled to a four-hour workday, the men who drove them were expected to work an 18-hour day. These transit workers received no better treatment on the job than the vast majority of their passengers. Many lived in poverty with no health benefits, no holidays, no pension, and no job security.

Once the railroads connected the continental United States, the stagecoach disappeared as a mode of public transit, and in the late 19th century, various forms of street train systems emerged in major cities to transport the multitudes of poor laborers to and from work. Street train conductors and associated railway employees faced multiple challenges on the job that affected their safety and quality of service.

First, street trains ran on electricity. In the early days, blackouts could affect the timeliness of service, and that angered the riders. Second, lack of train safety education often led to fatalities for the railway employees, passengers, pedestrians, horse-drawn carriages, and other vehicles.

Early Labor Organization

In 1882, the first street railway union, the American Street Railway Association, was founded in Boston. Members of this union lobbied the city for increased safety precautions, more routes, and improved track maintenance. In 1883, the Knights of Labor Local 2878 was the first street railway labor union established in New York. The Knights of Labor was the largest and one of the most powerful labor organizations in the 1880s; the union's successful railroad strikes for eight-hour work days and improved working conditions led to a surge of union membership among railway workers.

However, it was dangerous for transit employees to belong to a union. For example, company spies were known to infiltrate union meetings and fire officers and all attendees. In 1885, transit unions across the United States drafted employment contracts for their members and demanded that they be signed by employers. If the workers' demands were not met, they would strike, thus shutting down service until their needs were met.

In 1892, transit union leaders organized a national convention to bring all of the transit unions together under a common name. The Amalgamated Association of Street Railway Employees of America—the first national union for public transit

employees—was established at this convention in Indianapolis, Indiana. This union is now called the Amalgamated Transit Union (ATU); it includes bus, train, subway, streetcar, and tram employees as its members.

Labor Laws

Due to aggressive union intervention and paralyzing strikes, the federal government passed many laws to improve labor conditions for railway employees. In 1898, the Erdman Act was passed to provide for mediation and voluntary arbitration for railroad workers, making it a criminal offense for railroads to dismiss employees or to discriminate against potential employees because of their union membership or activities.

In 1910, the federal government passed the Accidents Reports Act, which legalized a 10-hour workday and standardized pay scales and working conditions. In 1916, the Hours of Service Act reduced the workday from 10 to eight hours. In 1935, the federal government passed the Wagner Act, also known as the National Labor Relations Act, clearly establishing the right of all workers to organize and elect their representative for collective bargaining. The federal government also provided pensions and unemployment insurance for railroad employees. In 1952, the federal government ceased operation of the railroads, and other carriers took over. Nonetheless, employees and carriers reached an agreement on wage increases and working rules in a manner consistent with the existing federal laws.

Transport Workers Union of America

In 1934, the Transport Workers Union of America (TWU) was founded in New York. Originally, the union was comprised of workers from New York City's Interborough Rapid Transit (IRT) system. Unlike other unions of its time, the TWU's leadership refused to discriminate against any transit employee based on race, religion, gender, sexual orientation, or nationality. In the early 1930s, the TWU reserved porter jobs for minority workers discriminated against by every other union and fought hard to open up job opportunities for everyone.

In 1937, within a span of just six months, the TWU organized the entire New York City transit system. It signed six major contracts, which included unionization of two subways and 35,000

workers. In the early 1940s, transit workers from New York, Ohio, Nebraska, New Jersey, and Pennsylvania joined the TWU to fight for better health benefits, competitive salaries, nondiscrimination in employment, and increased professionalism in the industry. Today, most states have TWU chapters for airline, transit, railroad, and gaming employees.

United Transportation Union

In 1968, the Brotherhood of Railroad Trainmen, the Brotherhood of Locomotive Firemen and Enginemen, the Switchmen's Union of North America, the Order of Railway Conductors and Brakemen, the International Association of Railroad Employees, and the Railroad Yardmasters of America voted to approve their merger into the United Transportation Union (UTU). UTU is an AFL-CIO affiliate headquartered in North Olmsted, Ohio, representing 125,000 active and retired railroad, bus, and mass transit workers in the United States and Canada.

Other Protections

Public transit employees are highly concerned with safety because safety or security violations affect not only their performance but also their own personal safety. Even so, their complaints to their supervisors about major safety or security issues once went unheard, or the worker could even be punished for complaining. For this reason, the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) provides whistleblower protection for public transportation agency workers who want to report a safety or security issue. Public transit employees are protected under the 2007 National Transit Systems Authority Act (NTSA), 6 U.S.C. §1142, establishing retaliation protections for public transportation agency workers. Employees of providers of school bus, charter, or sightseeing transportation are covered under the Surface Transportation Assistance Act of 1982 (STAA).

To understand the drive to unionize among transit workers, consider the case of nonunionized workers with similar jobs and skills. For example, school bus drivers may work for a school district or a private company, but they tend to receive minimal or no training on the safe operation of a school bus, or on how to interact with student passengers. Quite often, the school bus drivers have

no union protection and no way to defend themselves from the assaults of their passengers. Fifty-five-year-old Gregory Davis, a school bus driver in Richmond, Virginia, filed a lawsuit against the Richmond City School District for unjustified termination after several student passengers attacked him while driving. Although the students were charged with assault, the school district based its decision to terminate Davis on a Virginia code that stated that public school employees may be suspended if their behavior threatens the safety and welfare of students.

Employment Discrimination

Historically, racial and gender discrimination has existed in the American public transit industry. People of color have often been barred from serving as train conductors and flight attendants; to this day, the majority of flight attendants are white. Women remain underrepresented as pilots, although this may change with the increasing number of female Air Force veterans returning to the civilian workforce. Increased diversity within the public transit employee population came from state and federal civil rights legislation.

Public transit union leadership is diverse, reflecting the union membership. The Transport Workers Union (TWU) of the AFL-CIO has stated its commitment to supporting diversity and ending discrimination. In 1961, TWU President Michael J. Quill introduced Reverend Martin Luther King, Jr., as a speaker at the organization's annual national convention as a gesture of the union's support to eliminate discrimination within the bus companies and to fight against segregated busing in the South.

Today, TWU also has special committees to address issues related to women and veterans employed in the airline industry. Yet, at the time of this writing, TWU has no specific body to address equity issues based on race or sexual orientation and gender identity. The Amalgamated Transit Union (ATU) has a diverse union leadership, but aside from providing policies that address how ATU will handle sexual harassment, the organization has made no statements as to how the union will defend employees against discrimination claims.

Historically, public transit employees have worn uniforms and have been subject to strict dress codes. As public transit employees become more

diverse in religious and cultural beliefs, they will want to wear head coverings, hair styles, facial hair, or other attire that does not comply with the company dress code. Multiple lawsuits have been filed by public transit employees against employers who told them they could not wear crosses, nose rings, or long skirts instead of trousers.

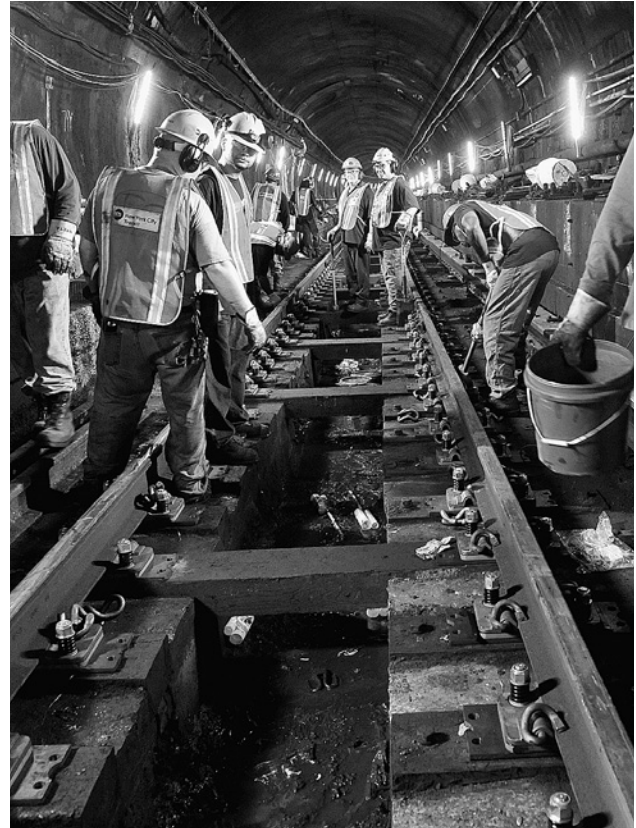
Public Transit Employee Benefits

In the 21st century, transit employees who work for the city, county, or state are considered city, county, or state employees. They are subject to the same antidiscrimination policies as other employees, and their pay scale is determined in negotiations between their union and the city, county, or state transit authority. Full-time public transit employees receive health benefits, sick leave, vacation time, overtime if they work more than the allotted hours within their shift, and some type of retirement package or pension.

The American Public Transportation Association (APTA) is an advocacy organization focused on the advancement of the transit industry. It represents public transit employee and administration interests at the federal level, organizing public transit systems to lobby on matters related to federal assistance, regulations, compliance, policy, and legislation. APTA collects information on public transit industries and provides a voice to the media on public transit issues. It has a scholarship program for students interested in pursuing public transportation as a career field and provides opportunities for networking. APTA also offers workshops and conferences to provide training on technological, legal, policy, and promotional updates in all areas of public transit. Most importantly, APTA seeks to improve security on public transit for the safety of employees and passengers.

Privatization of Public Transit Services

Many governments, in response to budget cuts, rising costs, and declining productivity, have considered or implemented the privatization of public transit to improve cost-effectiveness. Supporters of transit privatization claim that publicly owned, state-subsidized transit operations are inefficient because of their higher labor costs, restrictive work rules, and large bureaucracies. Critics of privatization insist that market failures counteract the benefits of privatization, resulting in under-insurance,



Track workers with the Metropolitan Transportation Authority of New York repair subway rails on August 9, 2013. According to the Bureau of Labor Statistics, the transportation industry had the greatest number of days missed from work due to injury as well as the second-greatest number of fatal accidents.

inconsistent vehicle maintenance, higher accident rates, and other deficits.

Contracting is the most common form of privatization in the United States. It allows the public agency to handle planning, routes, and scheduling coordination, while the private companies own, maintain, and operate vehicles, and hire labor. Private companies will aim to provide the lowest cost for service and the highest level of efficiency in order to compete with other entities for the contract.

Up until the 1960s, most bus transit firms in the United States were privately owned. Rapid growth in automobile usage caused ridership to decrease, especially for off-peak and weekend trips. In response to the increasing financial troubles faced by bus lines, the federal government passed the Urban Mass Transportation Act (UMTA) in 1964.

UMTA increased federal involvement and funding for failing transit firms. As subsidies increased, the cost of transit continued to rise faster than inflation, while productivity declined.

Traditionally, cost-efficiency in privatization of transit services was achieved through a non-unionized workforce. Today, private transit companies cannot deny employees union membership, although their wages may still be lower. The majority of cost savings that come from privatization come from leaner health care and retirement benefits of contracted employees.

Because state and federal policies aim to ensure transit access for the poor and disabled—as well as the general public—public agencies will most likely continue to maintain adequate service coverage and low fares. At the same time, privatization will cause salaries and benefits of public transportation employees to decrease.

Automation of Public Transit Services

To increase cost-efficiency, certain public transit jobs have been eliminated and replaced by automation. Human ticket sellers, as well as ticket collectors, are being replaced by ATM-like machines that allow riders to electronically transfer money onto a swipe card. This card gets swiped by the passenger either upon entry to a train platform or when entering a bus. While this type of system has reduced the number of public transit employees working in stations and the vehicles themselves, it has made rides more likely to run on schedule by reducing customer-driver interactions.

Human vehicle operators are concerned that a time will come when there is complete automation of transit vehicles. Vancouver, Washington, currently has the world's largest system of driverless metro trains. If an emergency takes place on the train, anyone on board can press an emergency intercom button and speak with someone in a central control center. In some other countries, automation is being combined with personalization in mass transit. Personal Rapid Transit (PRT) depends on fully automated "podcars" programmed to run on a track at particular times, stop at the station for passengers who indicate their need to get on, and then stop at the desired destinations of those passengers.

In 2013, the U.S. Department of Transportation began to solicit input on "surface transportation system automation," which would eliminate human vehicle operators. Unions are defending the rights of their employees to continue working in transit careers and are doing their best to protect their interests in this new technological age.

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See Also: Airline Pilots and Crews, Labor Issues of; Automated Transit Systems; Personal Rapid Transit; Privatization of Public Transit; Railroad Automation Technology; Transit Finance; Urban Mass Transit Act of 1964; Urban Mass Transportation Assistance Act of 1970.

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Queuing and Shockwave Measurement

A queue is a group of people or vehicles waiting for their turn for something—whether to be served by a cashier when queuing up in line at a retail store or to pass through an intersection. A queue can either be formal and organized, as with the first-come, first served line to purchase a bus ticket, or informal and disorganized or self-organizing, as with the jumble of people rushing to board an arriving bus. Queuing is the handling and organizing of the waiting elements of a queue. A police officer or other official directing traffic with a hand-held stop sign at the site of utility work or an accident is queueing traffic directly, for instance.

Queuing theory is the mathematical study of queues and the construction of mathematical models and simulations in order to investigate the effects of different actions, choices, or traffic events or features on queue lengths and wait times. Queuing theory, which originated in telecommunications, has applications in numerous areas (it is used in the design of hospitals and hospital procedure, for instance), and is especially important in traffic engineering.

Shockwaves

Shockwaves are propagating waves caused by an abrupt change to the medium through which they

pass (in mechanics, a “shock” is a transient excitation caused by a sudden acceleration), and resulting in a rapid rise of density to the flow of that medium. The properties and behavior of shockwaves can be examined and discussed independently of the environment in which they occur—that is, behaviorally, the shockwaves in the air caused by a detonation and the shockwaves in traffic caused by a traffic jam share important characteristics with each other.

In traffic, shockwaves are a result of queuing in congested conditions, and are propagating waves that move through traffic, noticeable in transition changes experienced sequentially by drivers as they are suddenly able to accelerate again after an idle period, or must slow down or stop again after a period of normal speed. While posing an inconvenience to drivers and resulting in inefficient fuel use and greater wear and tear, shockwaves more importantly pose a safety concern because of the increased opportunities for rear-end accidents.

From the right perspective—usually outside the car, unless traffic is going up or down a slope—shockwaves are visible as a cascade of brake lights. The transition change is caused not simply by the affected car passing into a part of the roadway where the capacity has changed. Rather, the lead car in the queue passes through an area where capacity has changed—perhaps because of a lane being shut down for an accident or because of an



Traffic backed up by an accident in New Britain, Connecticut, in September 2007. Rubbernecking at the scene of accidents or other road incidents can exacerbate shockwaves in traffic and can cause accidents. One study found rubbernecking to be the cause of 16 percent of distraction-related accidents in the era before smartphones and texting became a serious problem as well.

intersection or traffic signal—and in stopping or slowing because of that change, causes following traffic to stop or slow.

Shockwaves may be caused by capacity changes such as an increase or decrease in the number of lanes or an accident causing an obstruction, merging traffic, intersections, or traffic signals. However, it is important to note that heavy traffic is itself sufficient to cause shockwaves, since roadway capacity is a function of drivers as well as of the driving environment.

Shockwaves can affect drivers so far removed from the initial cause of the slowdown that it has been resolved by the time the farther-back drivers reach the incident area. Drivers are more likely to notice shockwaves that impede their travel, but increasing capacity in heavy traffic will also result in shockwaves of drivers being able to accelerate to greater speeds as the traffic ahead of them becomes less congested and the tight knot of the traffic jam loosens and frays.

Bottlenecks

Portions of a roadway where the capacity drops significantly relative to proximate sections of the same roadway are called bottlenecks, with the classic example being the narrowing of the roadway when the number of lanes is reduced, such as when approaching a bridge or tunnel or passing by an area of road construction. While traffic jams are caused by heavy traffic, a bottleneck is a specific reduction in capacity as a result of physical features of the roadway and can cause noticeable shockwaves even in light traffic. Some bottlenecks are the result of poor design, such as when a curve is too sharp and requires drivers to slow down substantially, or when traffic lights are badly timed and interfere with the steady rhythms of healthy traffic. Other times they are unavoidable temporary conditions, either because of an obstruction like construction or an accident, or because an especially busy traffic period (rush hour, or the Friday of Labor Day weekend) exceeds the roadway capacity. Bottlenecks are

vulnerable not only to traffic and safety issues but to security ones, and are frequently military targets.

Common causes of bottlenecks are the temporary closure of lanes due to construction or accidents, the narrowing of a multilane highway to a smaller number of lanes, poorly timed traffic signals; or slow-moving traffic. Slow-moving traffic can be caused by “rubbernecking,” which is a serious traffic ill. As drivers pass the site of an incident, whether an accident that caused a slowdown or a car that was pulled over by a patrol car or anything else, they slow down in order to have a better look at what happened. Even apart from the possibility that rubbernecking will itself contribute to accidents because drivers are distracted (and are changing speed at a time when drivers behind them are also distracted), it is a practice that exacerbates shockwaves in traffic. One study, conducted before smartphones and text messaging were popular in the United States, found rubbernecking to be the cause of 16 percent of distraction-related accidents. While its share is likely smaller now, it still has a substantial effect.

Traffic may slow for other reasons, though, particularly on one- or two-lane streets, where a single vehicle may be sufficient to slow the flow. This is often called a “moving bottleneck.” For instance, in farming communities tractors may slow traffic because their maximum safe speed is so much less than the posted speed limit on most roadways, and they are often too wide to pass even under normal passing conditions. On streets without sufficient shoulders, a mail delivery truck or newspaper deliveryperson may slow traffic unable to pass, by making frequent stops and having little opportunity to accelerate between them. And, of course, sometimes a driver is simply slow and impedes traffic behind him or her. Moving bottlenecks do not always result in shockwaves, though it depends on the roadway and the cause—here, the shockwaves would most likely be experienced by the traffic behind the mail truck, might be experienced briefly by the following traffic farthest behind the tractor in approaching the slowdown.

Analysis

To some degree shockwaves are unavoidable, at least without building roadways with capacities much greater than might ever be needed. Differences in speed contribute to shockwaves in traffic, for

instance. While most cars can respond to changing conditions such as a red light, merging traffic, or congestion up ahead in roughly the same time, smaller and lighter cars can respond more quickly without jolting their passengers, while tractor-trailers, buses, and other large vehicles require rather long distances to stop.

The speed of a shockwave is the speed at which the traffic disturbance associated with it is propagated through the traffic system. The speed of shockwave U_w is given by the formula:

$$U_w = q_c - q_B / k_c - k_B$$

Where q_c and q_B are the traffic flow rate of two sets of traffic conditions (c and B) and k_c and k_B are the densities in vehicles per mile of those conditions.

The usual description of traffic shockwaves as alternations between two states of driving (idling and free flow) is based on the classical conception of traffic as consisting of two phases free flow and congestion. Boris Kerner introduced an alternative three-phase theory in the late 1990s, proposing free flow, synchronized flow, and a wide moving jam (though “width” here is really referring to the length of the traffic jam end to end, not the number of lanes in which it transpires). In Kerner’s model, the “wide moving jam,” or J phase, is a disturbance in the traffic flow that moves upstream through bottlenecks and experiences numerous shockwaves. The synchronized flow, often with a downstream front at the bottleneck, is a continuous flow that might experience minor disturbances but nothing major, in which vehicle speeds become synchronized. This is a result both of the bottleneck that forces at least the fastest vehicles to slow down and of circumstances that make passing less likely.

One of the reasons the three-phase model is relevant is because it offers different explanations for traffic jams that are not caused by an obstruction, narrowing, or rubbernecking. Within the synchronized flow phase, narrow moving jams (minor perturbances) emerge in “pinch” regions where average vehicle speed slows down while vehicle density increases. These narrow moving jams can become J phases if they continue to grow or develop too close to one another.

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See Also: Traffic Congestion; Traffic Flow; Traffic Incident Management; Traffic Simulation; Transportation Modeling and Planning Software; Travel Modeling.

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Rail Corridor Congestion

Well into the second decade of the 21st century, United States national transportation policy remains shaped by a law passed in 1956. The Federal Highway Act of 1956—Dwight D. Eisenhower’s System of Interstate and Defense Highways—created the blueprint for the present roadway system in the United States and, along with it, changed the economic face of North America. The highway system forever altered rural areas, while expanding industry at a pace that was unprecedented. The highway, rail, and aviation networks have fostered new communities and connected cities, towns, and regions.

After more than 60 years and billions of dollars of investment, the United States has developed the world’s most advanced highway and aviation systems. Yet, these systems face mounting congestion and rising environmental costs. Moreover, the current transportation system consumes 70 percent of the nation’s total oil demand—much of it from overseas sources—and contributes 28 percent of its greenhouse gas emissions.

Current Challenges

While there is much attention in the United States focused on air-travel congestion and the high cost of fuel for highway driving, a crisis has also been developing for the transportation system used to

deliver most of the freight and many of the inter-city commuters in this country: the railroad system. North America’s 233,000-mile (375,000-kilometer) network of rails, devoted to carrying everything from passengers to grain and coal, is already under the strain of congestion.

The problem of tracks shared between freight and passenger trains has worsened in recent years as freight traffic has soared. Passenger trains move much faster than most freight trains, and in many areas there is only a single track, forcing trains to pull over onto side tracks and wait while trains coming in the other direction pass. Bottlenecks are increasing in many regions across the country.

The United States once had a thriving intercity rail and rail-based urban transit network. By the 1950s, however, the federal government shifted its infrastructure spending to highways and airports. Mass public transportation systems atrophied, and America’s technological leadership in the manufacture of everything from subway cars and trams to high-speed trains passed to companies in Japan and in France, Germany, and a few other European countries.

The loss of these industries in the 1970s and 1980s was largely a function of unstable demand rather than of high labor costs. As domestic demand for transit vehicles waned, U.S. companies did not keep up with state-of-the-art transit technologies. Continued underinvestment in infrastructure and

sustainable transportation options, meanwhile, left roads and bridges crumbling, mass transit systems in disrepair, and a transportation sector that accounts for almost one-third of our nation's greenhouse gas emissions.

Each year, traffic congestion costs Americans nearly \$90 billion in lost productivity and fuel purchases, with the average commuter losing nearly one full workweek sitting in traffic. Nearly half of all Americans lack alternatives to private automobiles and convenient access to public transit, which makes congestion even worse. Meanwhile, the lack of fully coordinated railroad investment means that, even with passenger rail traffic down, the improvements to the freight rail system have in many cases been undermined and stalled.

The existing public transit infrastructure suffers from decades of deferred maintenance. A recent report by the U.S. Department of Transportation (USDOT) found that the nation's public transit systems would need an immediate investment of over \$77 billion just to bring them into a state of good repair.

It is clear that the existing infrastructure is insufficient to handle the country's future passenger and freight mobility demands. An approach is needed that responds to economic, energy, and environmental challenges. The strategic goals as laid out by the U.S. government are to ensure safe and efficient transportation choices, build a foundation for economic competitiveness, promote energy efficiency and environmental quality, and support interconnected livable communities. Under this rubric and the new policies instituted through more recent legislation, freight rail corridor congestion in the United States is attracting more funding, and a turnaround may be in sight.

Legislation and Effects

In 1980, the Staggers Rail Act went into effect under the auspices of the Interstate Commerce Commission, now operating as the Surface Transportation Board (STB). This was largely a deregulation initiative designed to unlock the capacity of the U.S. private freight rail industry to expand, increase profits, and deliver higher quantity and quality of service.

The goals of the Staggers Rail Act are considered to have been achieved; for example, the metric of revenue-ton-mile is instructive, as data compiled by the Federal Railroad Administration (FRA) shows.

In the 30-year period of 1950 to 1979, railroad market share of revenue-ton-miles had decreased from 56.1 percent to 37.5 percent, with the market share shifting mainly to trucking and to waterborne and pipeline transportation modes. In the three decades between 1980 and 2010, railroad market share of revenue-ton-miles stabilized and edged up to more than 40 percent. This is the largest market share of any freight mode.

Regarding utility by distance, the FRA data indicate that rail is particularly dominant in the shipment of freight within the 500-mile to 1,500-mile (800-kilometer to 2,400-kilometer) sector of the freight industry. Rail also dominates in the transport of freight categories of bulk goods, manufactured goods, and consumer durable goods.

During the post-Staggers period, annualized improvements to both track and equipment have grown substantially, with more than \$500 billion invested cumulatively by the private freight rail companies, while rail accidents have declined by more than two-thirds. At the same time, freight rates halted their inflationary trend and have shown an average decline of 0.5 percent annually—even while freight rail company profits have increased.

By 2010 the U.S. freight rail industry comprised some \$60 billion in economic activity and shipped approximately 12.5 billion tons of freight per year. Projections by the STB were for 14.7 billion tons of rail freight in 2030 and 16.9 billion tons in 2050. These projections of increases of 22 percent and 35 percent, respectively, were based on a steady annual rate of 40.3 tons per capita, and of U.S. population increases to 366 million by 2030 and 420 million by 2050.

In 2009, President Barack Obama signed into law the American Recovery and Reinvestment Act (ARRA). As part of this legislation, the FRA has been charged with the distribution of \$8 billion for intercity and high-speed rail projects. The FRA has pledged to employ impartial evaluation criteria to judge applications (from all states applying), and to allocate this funding to only the most appropriate projects. The agency has outlined specific transportation, job recovery, project readiness, and other public-benefit criteria on which these applications are to be judged.

Defining which corridors are most appropriate for high-speed rail development is critical for the long-term success of this new federal program. The

\$8 billion appropriated for high-speed rail in the ARRA legislation is only a small fraction of what will be necessary to fully construct an American high-speed rail network.

Further, to maintain public support for a continued federal commitment to high-speed rail, the initial investments must be viewed as a success. There are huge potential financial risks inherent in any large-scale transportation infrastructure project. However, investing in corridors with the maximum potential to support such systems reduces this risk, increasing the probability of success and long-term public support.

It is helpful to clarify exactly what may be funded under this new program. There is no authoritative definition of what constitutes high-speed rail—and not all projects eligible for ARRA funding meet the definition of what international competitors consider high-speed rail. The European Union defines high-speed rail as separate lines built for speeds of 150 miles per hour (250 kilometers per hour [kph]), existing lines upgraded to speeds of 125 miles per hour (mph) (200 kph), or upgraded lines where speeds are constrained by circumstances such as topography or urban development.

In its “Vision for High-Speed Rail in America,” the FRA provides three definitions of high-speed service based on (1) distance between markets, (2) top speeds of service, and (3) existence of dedicated rights-of-way. The FRA 2009 High-Speed Rail Strategic Plan also defines three categories of high-speed-rail (HSR) corridors.

These categories are defined in terms of top speeds, track characteristics, and service frequency: (1) Core Express HSR corridors are up to 600 miles (960 kilometers) in length, achieve top speeds of at least 150 mph (240 kph), and use grade-separated track dedicated to passenger service in major population centers. (2) Regional HSR corridors are 100 to 500 miles (160 to 800 kilometers) in length, achieve top speeds of 110 to 150 mph (180 to 240 kph), and use dedicated and shared tracks to serve mid-sized urban areas and smaller communities. (3) Emerging HSR corridors are 100 to 500 miles (160 to 800 kilometers) in length, achieve top speeds of 90 to 110 mph (145 to 180 kph), use shared tracks, and serve moderate population centers and smaller, more distant areas. These services are also expected to be very competitive with air and auto trips in these markets.

The major effects on freight rail operations by implementation of the FRA plan could stem from new, streamlined railroad rights-of-way and the improvement of existing rights-of-way where congestion is at its worst. The lion's share of investment in freight-specific rights-of-way, however, is expected to originate from within the freight rail industry's companies and private investors. Still, every improvement in passenger rail corridor engineering and operations will yield the net effect of enhancing freight rail operations along those regional lines and systems. Additionally, the location and scale of various improvements to passenger rail facilities will impact the decision-making analysis of freight rail infrastructure, particularly as to the siting and engineering of intermodal freight handling, which has already become one of the most critical areas of freight rail investment.

The FRA, for its high-speed plans, has strategically invested in five megaregions: Seattle-Portland, Oregon; San Francisco-Los Angeles, California; North Carolina's Charlotte and Raleigh to Washington, D.C.; the Midwest Hub; and the Northeast Corridor. Collectively, these areas hold some 65 percent of the country's population, cover 33 states and the District of Columbia, and stand to absorb the bulk of future population growth. Each of these regions will be key to the future development of freight rail in America.

Recent Investments and Additional Programs

The United States has an opportunity to invest in public transportation and renew its manufacturing base. This country could gain more than 79,000 jobs in rail and bus manufacturing and related industries under an investment strategy that could double transit ridership in 20 years. If the United States were to invest at even higher levels—similar to those of China—this could yield more than a quarter of a million jobs.

The impact on freight rail will be similar in its growth potential across the United States. For example, some 221,000 jobs already are directly or secondarily created and funded through the freight rail industry, according to the FRA. These workers are employed largely by the country's seven Class I railroads (operating revenues over \$433 million) and by 21 regional and 510 local railroad companies.

It is not too late for the United States to follow the strategy of European nations and China in building a strong transit-vehicle industry. If more stimulus funds were directed to rail infrastructure and to public transit, the United States could develop world-class public transportation and create highly needed jobs, while helping to reduce urban traffic congestion and greenhouse gas emissions in the nation's cities.

The Transportation Investment Generating Economic Recovery, or TIGER, Discretionary Grant program provides a unique opportunity for the USDOT to invest in road, rail, transit, and ship port projects that promise to achieve critical national objectives. Congress dedicated \$1.5 billion for TIGER I, \$600 million for TIGER II, and more than \$526 million for TIGER III. Eligible projects include freight rail projects and high-speed and intercity passenger rail projects.

As of 2013, the FRA was administering more than \$328 million in TIGER funds. The program enables the USDOT to use a rigorous process to select projects with exceptional benefits, explore ways to deliver projects faster, save on construction costs, and make investments in the nation's infrastructure that make communities more livable and sustainable. Further benefits accrue both nationally and regionally as the private-industry owners and operators of freight rail systems are able to tap into, adopt, and adapt for their needs many of the technological and engineering achievements attained in the pursuit of these improvements to passenger rail. This is, in effect, a direct force multiplier as the environmental, economic, jobs, and quality-of-life improvements are accelerated through better planning, construction, operation, monitoring, and upgrading of the freight rail infrastructure that supports more communities also served by the improved passenger rail networks.

Managed by the Federal Transit Association's (FTA) Office of Research, Demonstration and Innovation, the Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) program works directly with public transportation agencies to implement new strategies for reducing greenhouse gas emissions and/or reduce energy use within transit operations. These strategies can be implemented through operational or technological enhancements or innovations. Initiated within the American Recovery & Reinvestment Act (ARRA) of 2009, the TIGGER program continues to support public transit

agencies for capital investments that will reduce the energy consumption or greenhouse gas emissions within their public transportation systems. Demand for TIGER and TIGGER grants far outstripped the resources available, with the USDOT receiving over 1,500 proposals that totaled more than \$58 billion, despite initial allocations of just \$1.5 billion for TIGER and \$100 million for TIGGER.

The National Cooperative Rail Research Program (NCRRP), initiated in spring 2012, was authorized as part of the Passenger Rail Investment and Improvement Act of 2008 (PRIIA) to conduct applied research on problems that are shared by freight, intercity passenger (including high-speed rail), and commuter-rail operators. The NCRRP undertakes research and other technical activities in a variety of rail subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The program is sponsored by the FRA, with program oversight provided by an independent governing board (the NCRRP Oversight Committee) appointed by the secretary of the USDOT.

Under all of these programs, the Transportation Research Board of the National Academies (TRB) organizes panels of experts to provide guidance on technical aspects of the research and to translate the problems into project statements with well-defined objectives. Research proposals are then solicited from private and public research organizations with capability and experience in the problem areas to be studied. The technical panels review the proposals, recommend contract awards, monitor research in progress, provide technical guidance, and determine the acceptability of the final reports. More than 3,000 experienced practitioners and research specialists currently serve on Cooperative Research Program panels.

Global Outlook

In the face of challenges such as high gasoline prices, traffic congestion, and carbon footprints, public transportation offers a range of benefits over private automobile travel.

Unfortunately, the United States lags behind China and many other countries both in maintaining and expanding its public transit infrastructure, as well as in creating the high-paying manufacturing jobs that can go along with this investment. Four nations that have retained significant manufacturing

employment in the rail and transit industries are Germany, Spain, Japan, and China.

China planned to spend nearly \$293 billion to meet its 2012 goals for high-speed rail and other rail and transit expansion. In addition to a world-class train network, China is using the initiative to create 6 million jobs and generate demand for 20 million tons of domestic steel. China is expected to account for more than half of global rail equipment expenditures in coming years.

Germany is Europe's largest rail and transit market, and one of the largest in the world. Although the United States has almost four times the population of Germany, both countries have about the same number of mass transit passengers. Germany's rail manufacturing industry remains a global technology leader, with a foundation of strong internal demand and even larger export sales. Germany's per capita investments in rail and transit are double those of the United States. Direct and indirect jobs in rail manufacturing amount to almost 200,000; if rail construction and operations are included, the number rises to 580,000.

Spain is a highly progressive rail power, maintaining the largest high-speed rail construction program in Europe. It is benefiting from a marked increase in rail ridership. Rail travel increased 55 percent between 1990 and 2008, far outstripping population growth. The Spanish government's 2004 Strategic Plan for Infrastructures and Transport (PEIT) served as an innovative planning tool, calling for 44 percent of total transportation investment to be directed toward rail, primarily for expansion of the high-speed network. Spanish companies that provide goods and services exclusively to the rail sector employed about 116,000 people in 2008.

Japan has been a pioneer in high-speed rail development (first utilizing high-speed rail in 1964) and continues to be a global leader. However, the country's declining population will limit domestic demand for rail services. Japanese rolling stock manufacturers are looking increasingly to the burgeoning global market; exports accounted for 38 percent of their revenues over the past decade. Some 25,000 people are employed in the production of rail equipment, parts, and signal and safety equipment in Japan, with many times more employed in component-parts supply chains.

Except for China, these and other countries have entered the U.S. market to supplement the stable

internal demand for equipment in their own countries that resulted from significant investment in their rail systems. These leading railcar manufacturers include Bombardier (Canada), Kawasaki (Japan), Alstom (France), Hyundai-Rotem (South Korea), Kinkisharyo (Japan), and Siemens (Germany). To meet Buy America requirements, some foreign suppliers of parts and component systems have established permanent U.S. facilities, while others make temporary use of local subcontractors.

The United States is finally making a turnaround in its commitment to public transit, but the level of investment so far pales in comparison to that of many European and Asian nations. While ARRA represents a significant one-time boost to U.S. public transportation funding, it remains unclear how much in regular annual appropriations will be made available in coming years.

It is beyond question, however, that major investments that are magnitudes higher than current spending will be necessary, and must be carried out over several decades, to satisfy future needs. The United States needs to dramatically increase its investment in public transit infrastructure in order to build systems that increase ridership, help to reduce congestion in metropolitan areas, lower greenhouse gas emissions, and create much-needed manufacturing jobs.

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See Also: Economic Development; Green Transportation; High Speed Rail, Policy and Planning of; High Speed Rail, Safety Issues of; International Rail Transit; Railroad Industry, Economics of; Train Stations, Economics of; Transportation Planning.

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Rail Transit Planning, U.S.

Rail transit systems are a diverse array of transport types using a fixed guideway or rail, each of which plays a different role in transportation in the United States. Whereas intercity passenger rail systems generally connect large metropolitan areas (for example, Amtrak between New York and Chicago) and are scaled to the national level, rail transit systems are designed to span regional or metropolitan areas. Commuter rail provides connectivity between an urban transportation hub and outlying communities (for example, the Long Island Railroad connects New York City with communities along Long Island), originally for the purpose of delivering workers to their jobs in the city. Light rail and subway systems more generally provide intraurban connectivity for people who need to get around within a city.

These classes of rail transportation differ not only in the scale at which their services are provided but also the frequency with which those services are provided. Rail transit systems generally run more frequently than intercity passenger rail; light rail and subway systems run more frequently still. However, they are all part of the intermodal urban transportation network that provides mobility alternatives

to the automobile for workers, shoppers, and travelers across the United States.

Planning for and implementing rail transit systems can be a lengthy and expensive process. However, improvements in federal transportation policy, coupled with present challenges of highway congestion and degraded air quality, have resulted in more flexible planning and funding processes that enable cities, regions, and states to more responsively and transparently plan for and implement these systems. Cities in which rail transit forms a large component of its transportation systems are characterized by significantly higher transit ridership and transportation system performance when compared to cities that have bus-only or no alternative transportation systems. Robust rail transit systems contribute significantly to the reduction of urban highway congestion and the improvement of regional air quality.

Background

A publicly regulated private market for transportation services originally dominated intra-urban rail transit systems. However, with the advent of and competition from the automobile and the post–World War II low-density suburbanization of the U.S. population, these transit systems became financially unsustainable. As ridership plummeted, the private transportation companies had increasing difficulty turning a profit, because their fares were constrained by public regulatory authorities and they were increasingly competing with cheap gasoline, rapidly improving highway networks, and the automobile. Because the cities had developed a reliance on these services to ferry workers from suburban communities to their jobs in the city, they were forced by circumstance to assume financial and operational responsibility for these networks when private companies failed. With no federal support for their maintenance or renewal, though, these systems began to decay, along with the fabric of the inner city.

In the 1960s, the federal government developed a formal interest in rail transit when cities asked for financial assistance in maintaining and improving those systems as part of their economic redevelopment activities. Seen as a uniquely urban problem, the first federal support for rail transit came in the form of urban development aid. The federal urban mass transportation program began in 1961 under



A New Jersey Transit sign marks a federally funded construction project to reopen a previously abandoned section of rail called the Lackawanna Cut-Off, which ran for just under 30 miles, beginning in Hopatcong, New Jersey. The project began in 2011 and a phase that is just over 7 miles long is expected to be complete by 2016, with the possibility of further extensions.

the U.S. Housing and Home Finance Administration, which became the U.S. Department of Housing and Urban Development (HUD) in 1965. The Urban Mass Transportation Assistance Act of 1964 provided the first dedicated public transportation funding; it was renewed in 1970. These programs provided grants for up to 50 percent of the cost of transit capital improvements.

In 1973, the Federal-Aid Highway Act allowed the flexible allocation of highway funds to urban mass transit projects. The 1974 National Mass Transportation Assistance Act, administered by HUD, allowed federal funds to be used for transit operating expenses as well as construction costs. The federal urban transit program was transferred to the Department of Transportation (USDOT) in 1968 and called the U.S. Urban Mass Transportation Administration (UMTA). It was only in 1991, with the passage of the Intermodal Surface

Transportation Efficiency Act (ISTEA), that the Federal Transit Administration (FTA) was created as a modal agency on par with the Federal Highway Administration.

Planning for Rail Transit

The contemporary need for a rail transit system arises from a number of sources. Urban sprawl development in the United States that came following World War II has resulted in a dislocation of the workforce from the workplace and highway congestion resulting from the necessary commute. It has become apparent in many major cities that a mobility policy predicated on building more highway infrastructure mitigates neither congestion nor air quality degradation. Cities are seeking alternative transportation solutions, including rail transit, that will demonstrably reduce traffic congestion, increase worker and shopper mobility, improve air

quality by reducing the number of cars on the road, and improve the overall quality of urban life.

Although bus systems are relatively inexpensive, and flexible from funding and routing perspectives, they have limitations in the volume of riders they can accommodate and the speed with which they can travel (over the same congested roadways plied by the automobiles they are meant to replace). Bus transport also suffers from a social stigma that has yet to be overcome in most municipalities.

Compared to bus transit, a rail transit solution requires significantly greater planning, incurs a much greater implementation cost, and requires more extensive supporting infrastructure. Further, because a rail transit network is rarely as dense as one achievable by a bus network, its success is dependent on the residential and business density in the vicinity of rail transit stations. Finally, because of the relatively limited number of stations in a rail transit system (compared to a bus transit system), its success is dependent on its connection to and integration with a denser network of bus transit.

Traditionally, the federal government has played a central role in providing financial support for urban transportation systems. However, it delegated planning, design, construction, operation, and maintenance of these systems to state and local authorities.

With the passage of ISTEA in 1991, the federal government shifted its emphasis from construction of the interstate highway system (by then nearly complete) toward roadway maintenance, as well as the development of more integrated transportation systems that could better serve diverse constituencies (including those in urban areas). The act encouraged intermodal transportation planning conducted at the local and state levels that more transparently engaged transportation system stakeholders and the private sector. More flexibility in spending funds previously dedicated to highways would be granted to projects developed to meet changing transportation demands reflecting economic, demographic, and environmental trends.

Metropolitan planning organizations (MPOs) arose in the 1960s as regional agencies were tasked by the federal government with creating long-range metropolitan transportation plans (MTPs) and short-range, prioritized capital investment plans (transportation improvement plans, known as TIPs). When contemplating a major investment

using federal funds, MPOs are required to conduct a Major Investment Study (MIS) exploring in detail the suitability and performance of competing design and implementation alternatives. Project proposals and planning initiatives eligible for federal financing assistance percolate up from the local/regional level through modally integrated MTPs and TIPs to the state transportation improvement programs (STIPs). The STIPs are submitted to the USDOT for evaluation and funding decisions.

Rail Transit, Development, and the Environment

In addition to its obvious contributions to a diverse and efficient urban transportation system, rail transit can play a large role in a municipality's sustainable development initiatives. A rail transit system can contribute to the reduction of automobile vehicle miles traveled (at least along the system's routes), aid in reducing urban highway congestion and the need for automobile parking in the urban core, and play a significant role in a city's portfolio of air quality management initiatives.

From an economic perspective, rail transit not only connects workers to their workplaces and consumers to the businesses they patronize, but it also provides a focus for residential, retail, and office location and development decisions. Just as land development often tends to concentrate around turnpike exits, commercial and residential development can be stimulated by the creation of stations along a rail transit route. Transit-oriented development (TOD) initiatives that specifically encourage such development have capitalized on the synergy between transit ridership and economic development by planning for the collocation of residential and commercial development around transit stations. As a result, many riders can reduce their dependence on the automobile.

Highway congestion and its concomitant increase in stop-and-go driving and engine idling have a significantly negative impact on air quality. The ISTEA of 1991 created the Congestion Mitigation and Air Quality (CMAQ) program (reauthorized in all subsequent surface transportation bills), which funds transportation projects or programs that will contribute to attainment or maintenance of the national ambient air quality standards for ozone, carbon monoxide, and particulate matter. The program enables metropolitan regions to

address transportation-related challenges to air quality through implementing congestion mitigation strategies. To the extent that transportation alternatives such as rail transit could aid in reducing the economic costs associated with urban highway congestion and improve regional air quality associated with that congestion, funding available through CMAQ can be allocated to these projects. Examples of projects that are eligible for funding with CMAQ funds include new transit facilities, new transit vehicles, and operating assistance for new or extended transit programs.

Present Funding

Prior to the 1980s, federal funding of surface transportation projects did not require that planners rationalize various transportation solutions into an integrated, multimodal surface transportation system. The first step taken to combine highway, transit, and safety authorizations came in 1982 with the passage of the Surface Transportation Assistance Act. In 1991, ISTEA created a unified surface transportation program with increased intermodal funding flexibility.

Congress has yet to designate a dedicated funding source for the mass transit account in the Highway Trust Fund (HTF) that was created in 1982 under the Surface Transportation Assistance Act. As eligible transit projects are designated for funding, monies are transferred from the highway account of the HTF to the mass transit account. When funds are transferred to FTA, they are allocated to one of three accounts: the Urbanized Area Formula Program, the Non-Urbanized Area Formula Program, and the Elderly and Persons with Disabilities Program.

The Move Ahead for Progress in the 21st Century Act (MAP-21) is the 2012 reauthorization of the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act (SAFETEA-LU), the federal surface transportation funding legislation. The Federal Funding Transportation Act, part of MAP-21, restructured the federal transit program. It established goals for the federal transit program, which include the following:

- Increase availability and accessibility of public transportation
- Promote environmental benefits of public transportation

- Improve safety of public transportation
- Achieve and maintain a state of good repair of public transportation
- Provide an efficient and reliable alternative to congested roadways
- Increase the affordability of transportation for all users
- Maximize economic development opportunities

While these goals are not specifically incorporated into the programs, or the progress toward them measured, MAP-21 does move the federal transportation program toward a performance-based approach for funding recipients, including the use of performance measures for maintaining systems in a state of good repair, transit safety, and congestion mitigation and air quality.

Transit programs under MAP-21 also include provisions that promote TOD. These include the establishment of a national goal for the encouragement of mixed-use, transit-oriented development and the creation of a TOD planning grant pilot program.

Immediate Prospects

Ridership on intra-urban transit systems is at an all-time high. Unfortunately, federal funding for the creation, extension, operation, and maintenance of these systems remains contingent on the health of the Highway Trust Fund. Recent economic sluggishness and increasing fuel efficiency have reduced fuel tax revenue, which comprises 90 percent of the HTF, and those dips have required three federal general fund transfers since 2007 to keep the HTF solvent. Because the mass transit account of the HTF is funded by only 2.86 cents of the gasoline tax (compared to 15.44 cents accrued to the highway account), funding for rail transit projects is particularly threatened. However, because rail transit systems provide strong congestion mitigation, air quality, and economic development impacts, an increasing number of cities are moving ahead with the planning and construction of new systems or expansions of existing ones.

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See Also: Congestion Mitigation and Air Quality Program; Federal Transit Administration; Regional

Transit Agencies; Transit Corridor Planning; Transit Systems; Urban Sprawl Versus Compact Development.

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Rail Transit Planning, Worldwide

The invention of fixed-line railway transit in the 18th century revolutionized the way people traveled and how they lived. For example, electric streetcars substantially increased daily travel distances and allowed towns to expand to suburbs that profoundly affected the form of cities. Subways achieved very high carrying capacities without taking much land for a right-of-way, which revolutionized how millions of people traveled in central business districts.

Rail transit systems changed economies by crossing continents and connecting cities. They continue to impact the lives of people, markets, and the built and natural environment. Further, changes in railway technology have been mirrored by shifts in transportation planning approaches, as well as the policies that affect how rail transit systems are operated. A great deal of diversity in rail transit services affects both planning and policy in different countries, and vice versa.

The type of rail transit service involved has implications for planning and operations. There are two primary types of rail systems: light rail transit (LRT) and heavy rail transit (HRT). LRT, including streetcars and tramways, tends to serve relatively dense urban areas and can operate on tracks embedded in the roadway or in a dedicated right-of-way. Mixing trains with car traffic, while it can reduce right-of-way acquisition costs, substantially lowers operating speeds and thereby increases travel time. However, light rail can move more slowly and still serve the needs of the community because it serves stations located relatively close together.

HRT generally operates on dedicated right-of-way traversing urban, suburban, and rural areas. It tends to have trains that travel faster and serve stations spread over a greater distance. The right-of-way of heavier rail is often shared with freight trains, which can impact the operation of either service, depending on which has priority in the corridor. Heavy rail also includes monorails and rapid transit systems (that is, subways or metros), which are used primarily for transporting people in dense urban environments.

Railway systems also vary dramatically by other characteristics. A railway system can form an extensive network with different types of rolling stock connecting many destinations, or be stand-alone line operated by a single agency or company. Some railway transit systems are intended to specifically serve urban needs. This is particularly true for rapid transit systems and LRT that serve different areas of a city or metropolitan region. These types of railways can be at grade, elevated, underground, or a combination.

Rail Transit and Its Effect on Economies

Existing railways have been built within a specific political context, based on the needs and resources of the population or operator and adapted to the local built and natural environment. Most of the railway networks currently found in less developed countries (LDCs) were built by colonial powers to further their own economic and military interests. The end of colonialism removed railways' major source of financing, as well as some of the initial justifications for subsidizing their infrastructure and operations.

A lack of investment in renewal or even basic maintenance of rail systems has led many lines to become dilapidated, leaving the community with

no alternative transportation infrastructure, or service in place. More recently, though, emerging economies (for example, Brazil, China, and India) have invested heavily in rehabilitating and expanding their rail transit networks.

Even among developed countries, investments in rail transit have been mixed. Railways initially had significant impacts on the fate of U.S. towns—impacting development patterns and changing the built environment. A close connection between real estate development and rail investment can be traced to the earliest history of rail systems in many countries, including LDCs. An increase in access by new rail service would often lead to higher demand for land around stations, and possibly along the entire corridor, thereby increasing property values.

Regions' economies were changed by the access rail transit provided to both businesses and employees. However, many lines declined in the post–World War II era, when there were massive increases in road investments and automobile ownership. In the past few decades, though, there has been a resurgence of interest in using transit-oriented development (TOD). TOD combines the provision of rail transit with land use and real estate development so that the built environment around stations supports transit ridership, while the presence of stations enhances economic and social activities.

Many European countries and emerging economies have expanded their rail transit networks strategically, primarily by investing copiously in urban railway networks and high-speed railways. Urban transit systems have been built or extended when congestion on the existing transportation infrastructure is insufficient to meet current or projected demand. In the past five decades, several countries (for example, China, France, Germany, Japan, and Spain) have added high-speed rail networks—often on dedicated rights-of-way to separate these trains from slower ones. These long-distance lines have stimulated economic development (tourism, business travel, etc.) between cities, regions, and even nations.

Connecting these railway systems across national borders has traditionally been limited in many regions. Some countries intentionally designed railway systems to be incompatible with those of their neighbors in the interest of national security. Although many European countries have enhanced their cross-border connections, other nations have

been either unwilling or unable to make compatible systems. This has limited the opportunities for trade as well as for travel between countries, notably in infrastructure-poor Africa.

High Costs But Mixed Returns

Another key factor affecting the planning process for rail transit is cost-effectiveness. Large public transportation projects, including rail projects, are often found to have significant cost overruns, while performance and usage are often lower than projected. This results in substantially lower cost-effectiveness than expected based on planning studies.

The level of railway investment varies by its type and scale, availability of right-of-way, geographic conditions, and engineering specifications. In regard to intra-urban rail systems, LRT has been attracting substantial attention for its lower capital cost relative to HRT and the positive economic impacts anticipated for station neighborhoods and the transit corridor. Their outcomes, however, still vary significantly by place. Rail transit projects require a lot of capital investment for construction and maintenance, and, once built, many of them must depend on subsidies to operate their service. All of this adds up to a need for substantial public investment.

Evaluating the effectiveness of rail transit services in the planning process also often involves comparing them to competing modes, particularly road-based travel. Where roadway infrastructure is already developed and costs of owning and operating automobiles are not expensive, rail transit systems are not typically profitable, particularly those that provide passenger service. Moreover, motor vehicles can drive over poorly maintained roads and even unpaved surfaces, whereas trains require a well-maintained infrastructure or they risk derailment.

The fact that motor vehicle owners are responsible for their own operation and maintenance costs also makes this mode more appealing to those who balk at rail transit's need for public subsidies. The inability of most rail transit to cover even its operating costs has actually led to deferred maintenance and eventually to the need for costlier renewal projects. However, railways are recognized as one of the most environmentally friendly modes of transportation when used efficiently, especially when ridership is high. They also have the ability to provide more affordable transportation to users than if they had to own and operate their own vehicles. These

arguments have rekindled interest in rail transit in areas with the potential for high ridership.

While transporting passengers can be undesirable from an internal financial perspective, rail transit has also been justified based on its ability to stimulate the local and regional economy. The concept remains relevant in the idea of “value capture” approaches, through which the public sector aims at a recovery of at least part of its capital investment in the rail system, either through increases in tax revenue or directly through income generated on publicly owned TOD (for example, Hong Kong). However, the effectiveness of value capture depends on a number of factors, including the regional economy and real estate market, other transportation projects, local land use regulations, the local planning process, etc.

Planning Considerations

Regardless of the motivations behind the proposal, planning for new railway projects is a complicated and expensive endeavor. It generally involves preliminary planning studies and analyses of alternatives, environmental impact studies, and more detailed engineering studies. Funding for studies or construction can be secured from private sources and/or various levels of government at almost any stage of the planning process. Official hearings and public outreach are usually required and, in developed countries, their timing is often specified by regulation in order to ensure adequate consideration of varying viewpoints.

Given the significant levels of resources involved, as well as the myriad stakeholders who have different and sometimes competing interests, the planning and construction of rail transit can also be very contentious. Various constituents impact railway transit planning and policy decisions to differing degrees. Governments and their representatives (that is, public officials, experts, and bureaucrats) have played a large role in the planning, financing, construction, and even the operation of railways. Not only does government often decide whether to build railways it has played a central role in determining the type of railway to build and planning where the tracks and stations should be located.

Various public agencies help regulate railways once built, even if they are privately operated. Many countries’ national passenger railway service is provided by a public entity, and the same is often true at the regional and local level. Although politicians

and government officials may sometimes adequately represent the transportation perspectives of the society, the public is often called upon to directly express their perspectives in the planning process. Sometimes members of the public even sit on advisory committees as a means of providing feedback to transit agencies on their operations and policy changes.

The private sector has played different roles when it comes to rail transit. Private-sector promoters of early U.S. railway systems aimed to stimulate development by making transportation easier, cheaper, and faster. Many private interests built and operated passenger railway systems to make land more attractive for development. In some countries during the colonial period, colonialists lobbied their territories’ administration to construct new lines to better serve their interests. Although responsibility for the provision and operation of rail transit largely fell to the state after World War II, private-sector companies continue to participate in the planning, construction, and operation of many railway transit systems. In fact, the current trend has been to increase private-sector participation to the greatest degree feasible, given political, economic, and other practical constraints on governments.

This usually involves privatization wherein the government retains ownership of the right-of-way while a concessionaire takes responsibility for operations and even maintenance of the railway service. These concession deals can open up the right-of-way to multiple operators, which theoretically increases competition, reduces operating costs, and increases the benefits to users. Privatization can accomplish this when railway companies have more efficient management than the public sector, encourage the use of creative and innovative approaches to marketing and operations, and reduce labor costs by cutting staff size, eliminating unions, and replacing higher-paid unionized workers with cheaper labor. Given the effort to reduce operating expenses by reducing pay, staffing, and service levels, it is not surprising that governments and the public have often resisted privatization policies.

International development institutions (IDIs), which include both bilateral (for example, the U.S. Agency for International Development) and multilateral aid agencies (for example, the World Bank), have become important players in the provision and support of railways around the world. IDIs

became involved in rail transit issues for many reasons, including improving the allocation of public resources and stimulating development. They provide both capital financing and technical assistance to many governments that want to build, upgrade, or preserve their railway systems.

Occasionally, IDIs such as the World Bank have provided grants or loans to railway systems that have not been able to cover their operating costs. Critics have charged that countries that provide bilateral assistance have motivations that are not entirely altruistic. Tied-aid, where a certain portion of a financing package must be allocated to businesses from the loaning country, is common. The World Bank has also helped facilitate the privatization of many rail transit services.

Despite the contentious nature of decision-making processes affecting investments, it is clear that rail transit continues to have relevance for many people, economies, and geographical settings. The diversity of rail transit services around the world is a testament to their resilience and the power of those who shape them.

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See Also: Commuter Rail; Heavy Rail Transit; High Speed Rail, Policy and Planning of; International Rail Transit; Light Rail Transit; Privatization of Public Transit; Rail Transit Planning, U.S.; Railroads, Passenger; Transit-Oriented Development.

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Railroad Automation Technology

Railroads have led other forms of transportation in developing automated systems. The most obvious reason for this is the fact that trains operate on tracks, which provide an obvious form of guidance and keep trains from sharing the rails with other transport modes. This factor, along with a culture that supports continuous improvement, have encouraged development of automated train systems, which have been proven successful as parts of urban transit systems and in providing transportation at a very localized level, such as within airports.

In addition, the size, weight, and speed of train operation make it imperative to keep the rails and roadbed in good condition and to maintain sufficient spacing between trains. The enormity of these tasks, as well as the need to detect defects not visible to the naked eye, spurred the development of automated track inspection systems, automatic signal systems, and automatic train control systems.

Automatic Track Inspection

Since the beginning of rail travel, maintaining the quality of the rails and roadbed has been a primary concern. Due to the great weight and high speed of modern trains, the consequences of a failure can be severe, in terms of both economic losses and human injury or loss of life. Regular inspections of the rail and roadbed play an important role in ensuring safe operations. Originally, such inspections were carried out visually, but this process is both time-consuming and unable to identify internal defects. Development of better systems of inspection was partly motivated by information gained from investigations into serious accidents, such as a 1911 derailment in Manchester, New York, in which 29 people were killed and 60 seriously injured. The U.S. Bureau of Safety (now the National Transportation Safety Board) found the cause of the derailment to be a transverse fissure of a rail, a defect that could not be identified visually.

In the United States, the Bureau of Standards began experimenting with magnetic track inspection systems in 1915, and, in 1927, Elmer Sperry built an inspection railcar carrying equipment capable of detecting transverse fissures; it used a magnetic field to record irregularities in the track



A car on the Hartsfield-Jackson Atlanta International Airport (Georgia) Automated People Mover. The driverless train shuttles about 200,000 passengers a day between airport terminals, making it one of the busiest automated systems in the world.

and could identify transverse fissures, although other types of defects passed unnoticed. The next innovation in automated track inspection was the development of ultrasonic methods; ultrasonic rail testing was first used in 1949, and the first all-ultrasonic inspection car, developed for use in the New York City subway system, was completed in 1959.

A rail operator must know the current state of the tracks and roadbed in order to know the speed at which a train can be safely operated over a given route. To address this issue, the U.S. Federal Railroad Administration (FRA) inaugurated the Automated Track Inspection Program (ATIP) over 30 years ago, using geometry cars (specialized railcars that gather information about track alignment, surface conditions, etc.) to inspect about 30,000 miles of track per year, with the goal of increasing annual inspections to 100,000 miles of track.

Besides identifying defects, the ATIP also calculates the maximum safe speed of operation on curved segments of track. Priorities for the ATIP include stretches of track already known to present a safety hazard, routes used to transport hazard

materials, routes that form part of the Strategic Rail Corridor (STRACNET, that is, rail lines considered important to national defense), and passenger routes.

Automated Trains

There are several reasons why automation is particularly suited to railways, perhaps more than other modes of transit: they operate on tracks that provide a built-in guidance system and are used exclusively for trains; they transport large numbers of people over route systems with a limited number of stops; many of their systems, such as signaling and braking, already have a high degree of automation; and trains can operate at very high speeds that are near or beyond the ability of human beings to make judgments in real time. The earliest examples of automatic train operation (ATO) include the London Post Office Railway, which began operation over a 6.5-mile route in 1927, and the 42nd Street Shuttle in the New York City subway network, which was automated from 1959 to 1964.

In the United States, the Urban Mass Transportation Administration (UMTA), now the Federal Transit Administration (FTA), financed the development of fully automated (driverless) railways in several U.S. cities in the 1970s. Several of these cities dropped out of the program, but Miami and Detroit both built automatic railway systems, or people movers, under this program; Jacksonville, Florida, later built a people mover, as well. All three systems are centered on the downtown area of their respective cities. Miami's system, called the Metromover, has the most developed network and is the most successful, with substantial increases in ridership in recent years. In contrast, Detroit's People Mover has been plagued by low ridership and high operating costs, leading to labels such as "the horizontal elevator to nowhere" and "the rich folks' roller coaster."

A few urban subway or light rail systems have fully automated one or more lines, including the Paris Metro (Lines 1 and 14), the Barcelona Metro (Line 9), the Guangzhou Metro (Lines 4 and 5), the Budapest Metro (Line 2), and the Nuremberg Metro (RUBIN or U3 line). However, other systems have seen disadvantages to going to a fully automated, driverless system.

For instance, although some of the London Underground's operations in the United Kingdom are partially automated, when London Mayor Boris Johnson

suggested in May 2012 that the Underground should automate the Docklands Light Railway, the suggestion was met with strong opposition. Most of the objections to fully automated systems have to do with safety, with anecdotal evidence suggesting that human judgment may be superior in unusual circumstances, such as a child on the track or a train out of control and headed for imminent collision.

Fully automated trains are more common at airports, where they may operate within the terminal, as does the Automated People Mover at the Hartsfield-Jackson Atlanta International Airport (Georgia), or between terminals and other outdoor locations (for example, parking lots), as does the AirTrain at Newark Liberty International Airport (New Jersey).

These airport trains exemplify several of the advantages noted above for railway automation in general: they run over relatively short distances and carry large numbers of people to a limited number of destinations. For instance, the Automated People Mover carries about 200,000 passengers daily between terminals in the Atlanta airport, one of the busiest in the world; it is entirely underground and within the secure area of the airport.

Automatic Signaling and Train Control Systems

Because trains operate at high speed and on a limited system of rails, the possibility of a collision is particularly severe. Timetables were developed in part to make operations safer, but systems of signaling were also developed early in the history of the railroads to reduce the probability of collisions. One key to safe operations is block signaling, which divides railway tracks into sections called blocks and uses signals to inform train operators if the block ahead is clear.

Originally, such information was relayed by use of flags and hand signals, later replaced by hand-operated mechanical signals. Today, automated block signaling (ABS) is used in some areas where the frequency of the train service makes it difficult for manual operators to keep up with the traffic. ABS uses electronic methods to determine if a train is present in a block of track; if a train is present, a signal is sent to the preceding block to warn the operator of any train in that block to slow down or stop. Such systems are usually designed so that if they are not functioning properly (for example, if a wire connection is broken), the clear signal will not be given.

In an automatic train control (ATC) system, safeguards are incorporated into the rail system to supplement signal systems and to prevent trains from operating unsafely. For instance, in the New York City subway system, if a train passes a signal in the stop position, or exceeds the permissible speed, the train's brakes are automatically activated. Many passenger rail systems in the United States also use a speed control system, so that if a train exceeds the permitted speed on a line of rail, a signal is triggered in the cab, followed by the triggering of an automatic braking system if the train does not reduce speed.

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See Also: Airport Parking and Ground Transportation; Airport Transit Connections; Automated Guideway Transit; Automated Transit Systems; Monorails.

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Railroad Grade Crossings

Railroad grade crossings are the areas where streets, highways, and pathways intersect the rail track at grade or street level. Thus, rail grade crossings facilitate the movement of vehicles, people, and goods over the rail tracks. There are public and private rail grade crossings. Public crossings are open to the traveling public and are under the jurisdiction of and maintained by a public authority. Private crossings are on privately owned highways and pathways.

Rail grade crossings afford a safe, comfortable, and convenient passageway for all users that encourages lawful behavior. There are many different types of crossing material used in practice, including timber, asphalt, concrete, and rubber. The type of crossing material used is primarily determined by the volume of vehicular and nonmotorized traffic that uses the crossing, with additional considerations for drainage, access for maintenance, and pedestrian safety and accessibility.

In addition to rail grade crossings where a roadway and its sidewalks meet the rail tracks, grade crossings are used at or near commuter stations to facilitate the safe movement of boarding and alighting passengers between platforms, as well as of the public at large, to move from one side to the other side of the tracks. Grade crossings also are used at nonmotorist facilities, such as bicycle/walking trails, pedestrian-only facilities, and pedestrian malls.

Design Elements

The geometric design of a rail grade crossing requires consideration of the horizontal and vertical alignment, sight distance, and cross section of both the highway and the railroad. Other important design elements include the selection of an effective crossing surface that will permit smooth passage of vehicular and nonmotorized traffic across the tracks; the provision of signing and pavement or sidewalk marking to give adequate notice of the railroad crossing, and visibility to motorists, nonmotorists, and train operators; and the selection of appropriate warning devices for the crossing environment.

In general, the rail grade crossing design avoids abrupt changes in roadway/sidewalk alignment and grade to meet the railroad. Designing the grade crossing to provide as flat a roadway/sidewalk grade as practical through, and at either side of, the

crossing facilitates the safe passage of vehicular and nonvehicular traffic. Otherwise, the design requirements of grade crossings are similar as those for other roadway intersections.

It is desirable that the intersection angle of the grade crossing relative to the railroad tracks is as close to a right angle as is practical for the location, so that sight distances for both the road/sidewalk user and the train operator are optimized. Moreover, sidewalks and bicycle crossings with the railroad are more sensitive to the skew angle than the main road because of the possibility of bicycle or wheelchair wheels being trapped in the rail flange-way. In addition, obstructions such as vegetation, utility poles, and signs should be located so that the visibility of warning and other informational signs is not diminished.

Planning for Safety

Rail grade crossings, as intersections where trains, vehicles, and nonmotorized users meet, and where the train always has the right of way, are areas of potential conflict, because two or more modes of transportation cannot occupy the same space at the same time. Thus, rail grade crossings present potential conflicts for the movement of motorized and nonmotorized traffic that, unless regulated, would usually lead to catastrophic outcomes for crossing users and train passengers and staff, as well as incurring economic damage to all parties involved.

Improving the safety of rail grade crossings remains a challenging endeavor, especially for nonmotorized users such as cyclists and wheelchair users. This is because pedestrian-crossing incidents occur in different settings requiring the coordination of different stakeholders with context-sensitive solutions. For example, incidents involving violations at rail grade crossings are different than trespassing incidents away from such crossings. Pedestrian crossing incidents at exclusive pedestrian crossings (including rail stations) are different than those occurring at highway-rail grade crossings. Furthermore, incidents in crossings with commuter rail or light rail would require different countermeasures than those occurring in crossings with freight rail.

In general, the safety of grade crossings to vehicles, nonmotorists, and trains is increased with the deployment of crossing traffic control devices such as warning devices (for example, detectable

warnings for users with disabilities, automatic gates, etc.), signs (for example, highly reflective passive warning signs, dynamic signs, second-train-coming electronic warning signs, etc.), channelizing devices (for example, fencing, swing gates, and zigzag gates), as well as pavement markings.

Engineering standards and guidelines for crossing traffic control devices are provided by public and professional organizations. In the United States, for example, such organizations include the U.S. Department of Transportation, state utility commissions, the American Railway Engineering and Maintenance of Way Association, the American Public Transportation Association, and the U.S. Architectural and Transportation Barriers Compliance Board.

Different criteria are used to determine the suitable mix of warning devices and signs that can be deployed at rail grade crossings: (1) collision experience at the crossing; (2) frequency of inclement weather; (3) vehicular and nonmotorized volumes; (4) train speeds, number of trains, and railroad-traffic patterns; (5) surrounding land uses; (6) sight distance for approaching vehicles and nonmotorists; (7) skew angle of the crossing relative to the railroad tracks; (8) presence of multiple tracks; (9) vicinity to a station or platform; and (10) installation and maintenance costs. Engineering studies usually determine the types of warning devices that are necessary at each crossing location.

In order to improve safety at rail grade crossings, certain activities need to be routinely performed. First is a continually updated data inventory that includes the location of the crossing, traffic and train volumes, and physical elements and collision history of the crossing; second is a process for analyzing available data to identify hazardous crossing locations on the basis of collision experience or collision potential; third is a process for implementing and evaluating safety improvements; and fourth is education and enforcement campaigns for reducing user violations at rail grade crossings. Additional actions may be necessary in grade crossings with high-speed rail operations.

Interesting new developments in the area of cooperative Intelligent Transportation Systems (ITS) may soon bring to bear applications that could dramatically affect safety for users in grade crossings. Vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-consumer devices (V2D) are

being developed to deliver more safety mobility benefits. Drivers, pedestrians, and nonmotorized users, in general, at rail grade crossings will be able to receive personalized advance warning of incoming trains in time to avoid injuries and fatalities.

Risk Management

A consistent approach for managing the risk at rail grade crossings would assure (1) the uniformity and continuity of data collection programs, and administration of related databases, on all such crossings; (2) the analysis of risks at such crossings; (3) the prioritization of crossing upgrades; (4) the introduction of suitable risk controls; and (5) the assessment of cost-effectiveness of such measures.

Moreover, a program of risk management that includes expertise in the areas of engineering, education, enforcement, enabling, and evaluation (or “five Es”) could increase safety at rail grade crossings. This is because of the following:

- Engineering solutions can integrate the deployment of lights, horns, barriers, communications, and signs in innovative ways.
- Education initiatives can increase public awareness of the dangers of crossings, and educate pedestrians, road vehicle drivers, and other users how to use them correctly.
- Enforcement makes use of laws to prosecute those who endanger themselves or others by misuse of crossings.
- Enabling provides resources through people, procedures, and systems to allow activities in the other “Es” to be effective.
- Evaluation encourages organizations to set a baseline before embarking on new initiatives so that the before and after can be properly compared.

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See Also: Commuter Rail; Federal Railroad Administration; Heavy Rail Transit; High Speed Rail, Safety Issues of; Highway Safety Barriers and Traffic Barriers; Light Rail Transit.

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Railroad Industry, Economics of

A railroad is a form of transportation infrastructure that enables locomotives to drive various configurations of cargo and passenger cars from one node in the system of tracks to another. Railroads are customarily laid between two endpoints, and locomotives run between them—in two directions simultaneously after dual-track replaced single-track systems—passing through various stations along the way where passengers and cargo can be added or subtracted.

Because the locomotives and rolling stock roll along the parallel rails, changing directions is only possible at designated switching points, which are now operated electronically.

Infrastructure is a form of enabling technology that provides opportunities for people to use it for their own purposes, whether these are commercial or noncommercial in nature. Although such people will contribute some support to the railroad network through buying tickets or paying fees, they will by definition derive more benefit from the journey than the fare required; otherwise, they will not pay it, at least according to the theory of rational choice based in microeconomics.

Consequently, when seeking to quantify the benefit of a railroad, it is important to use a suitable multiplier figure because \$1 of investment will return more than \$1 of return. This is based on the assumption that the railroad is properly planned and constructed between nodes for which there is a demand for services.

Railroads cannot operate in isolation but rely on accompanying forms of infrastructure, including fuel supplies, repair facilities, stations with facilities for passengers, and equipment for loading and unloading cargo. It is apparent that providing all of these facilities is a large-scale undertaking that requires a substantial organization to take care of all of it.

In the case of India, which is perhaps the most notable example of a universal state-managed system, the organization managing the railways is enormous in scope and requires considerable amounts of finance, housing for employees, human resource support, and all the other functions required for a corporation of very large size. The organization has become a significant feature of the contemporary society and economy, and, potentially, within politics as well.

Construction of railroads in the developed world began in the 19th century and spread and intensified in the 20th century. Railroad building was a symbol of modernization and of nation-building in those countries, in addition to being an important tool for economic development. In a country such as the United States, where large low-population-density areas exist between major urban centers, the ability to attract a railroad through a rural community could mean the difference between whether that community was sustainable or not. People and businesses from neighboring communities would be likely to move to where the railroad station was located, so as to reduce transaction costs and because more customers were likely to congregate there. This is an example of how trade diversion can exist alongside trade creation, depending on the location of infrastructure.

Outside the developed world, the spread of the railroad in a country did not always elicit the same positive feeling, because it was often a sign of the intensification of colonization or the linking of local communities to distant markets over which local people can have little control. In Imperial China, for example, a fiercely contested debate took place before it was decided to permit foreign capital to enter the country to build railroads, and thus to connect Chinese territory and customs with the emerging international capitalist order.

It is not surprising that people were concerned, given the incredible level of corruption and graft that accompanied the construction of American

railroads, for example, not to mention the inhumane treatment of the thousands of Chinese laborers working on that construction.

In the colony of Burma (now Myanmar), the railroad, seen as a representative of the British Empire, was used as a means of connecting the gem mines of the interior with the coastal colonial capital of Rangoon, from which the products of Burmese labor were extracted for the benefit of a foreign crown.

Elements of Railroads and Ownership

In the United States, railroad construction was first driven by private investors seeing to make a profit by linking lively destinations, driving down costs through repressive workplace relations, and attempting to obtain concessions and subsidies from state and local government agencies. The violence with which the Pullman railroad strike of 1894 was crushed is viewed with astonishment by people of the current day.

By contrast, European railroad systems were mostly built by state-owned organizations that were mandated to take account of the need to unite distant communities with the center in the interest of the nation. Such systems placed railroads themselves, locomotives and rolling stock, and station facilities and maintenance under the control of a single organization. However, as facilities became more extensive and complex in nearly all the countries where they existed, it also became evident that differential management systems might be preferential.

Initially private, most of the railroads in the United States rolled into the public sector, although—turning full circle—the desire for privatization has been growing in intensity since the late 1970s. While this movement has involved some railroads, many (but not all) have become loss-making ventures lacking sufficient income. Consequently, various attempts have been made to divide railroads overall into component parts, including the distinction between maintenance of track and rolling stock, management of station facilities and concessions for retail opportunities within the station concourse. The results of privatization have, as ever, been mixed.

Private corporations have been willing to take on contracts in areas with high demand for services and have made large profits in some cases, such as some privatization projects in the United Kingdom. However, the public service aspect of railroad

provision is incompatible with profit seeking, and so remote areas have not been popular for privatization. Further, the separation of services by rail and stock rather than on a geographic basis, as has more successfully been managed in Japan, has contributed to a situation in which underinvestment has occurred and performance suffered as a result.

Station facilities exhibit a similar pattern, as some services have been subcontracted and have in some cases been made into profitable commercial activities. This has not always been a popular practice, although it has contributed to the convenience of contemporary urban living.

Railroad's Role in the Economic System

When seeking to calculate the rate of return from railroad investment, there are several approaches that can be used. These include the amount of passenger fares or cargo fees received per dollar of investment in the project, a calculation that would be appropriately adjusted for amortization of capital goods and the cost of capital. A more contemporary approach would also seek to incorporate the social and environmental impact of railroad project construction as part of the triple bottom line approach.

However, historically railroads have had a particularly important place in the development of economic thought, especially in the United States. In the first place, railroads were considered to be an important means of spreading economic growth throughout the continent. In other words, it was established that building a railroad promoted additional economic growth that would not otherwise have occurred at its various nodes, which means a multiplier effect is occurring and this should be considered a positive externality.

Further, railroads and their operation were used as direct inputs in the development of understanding of cost-estimate functions and, later, multiproduct pricing theory. The fact that railroads crossed multiple state borders and that data collection in the United States, being the best available, meant that this study was seminal for the understanding of uneven economic development and the impact of deregulation, which was handled differently on a state-by-state basis.

However, the role of railroads has become less relevant as alternative modes of transportation have been developed and as more value has become

attached to services and knowledge-based products that do not require physical transportation.

Railroads, in common with other forms of transportation, also have other forms of positive externality resulting from their existence. This includes the promotion of national identity, which was especially relevant during the period of modernizing nation-building. This is a process that remains important in countries with significantly different ethnic or linguistic groups.

In countries with land borders, railroads have also contributed significantly to economic growth on both sides of those borders by supplementing the seaports, which had previously been the principal means of exporting goods. Railroads also promote social stability and harmony by giving the means to people to travel for social and leisure purposes at comparatively low cost. Mass transit systems are preferable to personal automobiles for this reason, as well as the beneficial environmental implications.

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See Also: Freight Transport, Intermodal and Multimodal; Intermodal Freight Transport, Technology and; International Rail Transit; Railroads, Freight; Railroads, Passenger; Trains.

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Railroads, Freight

Freight trains are those trains that transport freight rather than passengers; they consist of a series of freight cars pulled by a locomotive or series of locomotives. Freight or cargo consists of goods transported for commercial purposes, and today they are primarily shipped in standardized containers that have been optimized for intermodal transport—meaning they are easily transferred from one mode of transport to another, such as from a cargo plane to a train, without need of repackaging.

When it is practical, rail transport is a cheaper and more energy-efficient means of freight transport than trucking, and the gains increase with distance. For shorter distances, the railways' lack of flexibility is a disadvantage. Intermodal transport is more and more common, with freight railroads forming an important component of the overall freight transport story. In addition to carrying ordinary cargo, freight trains are critical to the transport of steel, wood, and coal. Because these industries predate or grew up alongside the advent of the railways, their production facilities and the destinations of their goods are located along railway routes.

The use of standardized containers is called containerization. The containers, called shipping, freight, or intermodal containers in formal literature, and often just "boxes" in the industry, are reusable and come in standard sizes. Most are of a height and width appropriate for transport by truck or train and come in lengths of 20, 40, 45, or 53 feet. Inside the container, freight is kept steady with lashes, synthetic webbing, and steel straps, and airbags are inflated to fill empty space to prevent freight from shifting during loading, unloading, and transport. Containers stack up and next to each other and lock in place, ensuring safe cargo so long as the freight inside has been properly packed.

Containerization is the bedrock of the modern shipping industry, allowing for maximum packing efficiency of freight transport vehicles (with no unused space left over because of containers of incompatible sizes) while significantly reducing the amount of time it takes to load a freight car. Most major cities and ports have a container terminal, often near an airport or seaport, where freight is received and transferred to the vehicles that will bring it to its final destination.

One of the common types of train cars used for freight is the flat car, an open car consisting of a flat deck with some kind of mechanism on the sides for securing loads, which can range from simple tie-down points to sliding assemblies used to hold machinery in place. Flatcars are used for freight too large or unwieldy for enclosed cars, and in addition to the typical flatcar design, come in a variety of specialized freight designs, from “sky box” flatcars for transporting aircraft parts, bulkhead and center-beam flatcars that have open tops but sturdy walls to keep cargo inside, even flatcars used to transport circus equipment.

Containerization has popularized the use of well cars, which are railroad cars designed to hold containers. Their name comes from the depression close to the rails that allows the container to be carried lower than on a standard flatcar. This allows loaders to stack two containers one on top of the other, with a center of gravity low enough that the load is still stable. Well cars are a distinctly American freight car, since European rails tend to have less manageable overhead clearances, often due to electrification. Another flatcar design that accommodates containers is the spine car, which uses lateral arms to support them.

The most familiar freight car is likely the boxcar, an enclosed car used for general freight, with side doors and adjustable bulkheads. They are the most versatile car and were originally loaded manually, but today forklifts and other mechanical means are used for speedier and less dangerous loading. Transporting livestock in boxcars was standard until the late 19th century, but modified boxcars called stock cars are used today, which are better able to deal with the climate.

Stock cars have louvered sides for ventilation, and when transporting smaller animals like pigs or sheep, they are often separated into two or three levels. Specialized stock cars are even used to transport live fish, and have been since 1874, when 35,000 shad were transported to the Sacramento River to stock it. “Fish cars” were a popular novelty attraction at the turn of the century. Because of the relatively small size of chickens and similar birds, they were often transported in stock cars called wheeled henhouses, which were built with mesh walls and multiple levels of individual coops with food and water dispensers. Such cars required an attendant to travel with the birds to keep them fed



A freight train carries a series of relatively small cargo containers on flatcars near the village of Dombås, Norway. Freight is usually stabilized inside containers with lashes, synthetic webbing, steel straps, or airbags that are inflated to fill empty space.

and watered. Live poultry shipping is not quite as common now that cargo flights have become more common and affordable, and changes in the poultry industry have reduced the need.

Boxcars were also used to transport automobiles until the 1960s, with development of the autorack. An autorack is a specialized freight car that transports cars and pickup trucks from factories to distributors, often with a double-decker design in order to meet demand cost-efficiently.

Another specialized freight car is the gondola, which looks much like a boxcar from the side except for having low walls and an open top. Gondolas are named for the flat boats used to carry coal down rivers in the 19th century—themselves named for the more romantic boats of Venice. The freight cars used to carry coal have outlived the boats, though they are used for a number of other purposes now, similarly centered around dense cargo like minerals or metals. Metal coils, especially steel, are usually carried in coil steel cars, which replaced gondolas

for this purpose. A coil steel car has a series of troughs that cradle the coils, and usually a hood to cover the car after loading.

Today, there are over 500 common-carrier freight railroads operating in the United States. There are eight Class I railroads, the railroads with annual carrier operating revenues of at least \$250 million, adjusted for inflation, according to the Railroad Freight Price Index: Amtrak, BNSF Railway, Canadian National Railway, Canadian Pacific Railway, CSX Transportation, Norfolk Southern Railway, Union Pacific, and the Kansas City Southern Railway. Of these, only Amtrak is not a traditional freight railroad, focusing almost entirely on passenger service, though it does handle freight transport of packages, human remains, and a number of other small categories, and its tracks are used by freight transporters.

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See Also: Containerization/Container Shipping; Freight Transport, Intermodal and Multimodal; Intermodal Freight Transport, Technology and; International Rail Transit; Railroad Grade Crossings; Railroad Industry, Economics of; Railroads, Passenger; Train Stations, Economics of; Trains.

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Railroads, Passenger

Since 1869, when the Transcontinental Railroad was completed, a national rail service has played a key role in the United States' economic and transportation infrastructure. Through the mid-1940s, private railroads continued to play a dominant role in intercity passenger travel on a national scale. Plying the tracks of the freight rail industry, private-rail

passenger service between America's growing urban centers faced little competition from other modes of transportation.

Following World War II, however, as the economy boomed and passenger miles-traveled dramatically increased, automobile and air modes of transportation dominated government transportation funding. Beginning in the 1950s, highway and air transportation modes received the majority of government transportation funding. Even today, passenger rail has no dedicated funding source similar to the Highway Trust Fund, established in 1956 to pay for the interstate highway system and other roads, and the Airport and Airway Trust Fund, created in 1970 to increase capacity in the rapidly growing air transportation market.

Passenger rail, operating then within the private sector, was provided no such programmed government subsidy. Faced with the emerging dominance of the automobile and mass-market air travel in the early 1960s, private passenger railroads began to lose money on their passenger routes and, by 1970, most had gone out of business.

Amtrak and Early Interest in High-Speed Rail

Congressional interest in high-speed passenger rail can be traced back to 1965 with the passage of the High Speed Ground Transportation (HSGT) Act, which began a federal effort to develop and demonstrate "contemporary and advanced HSGT technologies." These efforts led to significant planning for, capital investments in, and service improvements in the Northeast Corridor linking Washington, D.C., and Boston, Massachusetts.

In 1970, Congress created the National Railroad Passenger Corporation—popularly known as Amtrak—as a private, for-profit, federally sponsored corporation to preserve intercity passenger service across the nation. In exchange for relieving private rail companies of their passenger responsibilities and associated financial losses, Amtrak was granted access to freight railroad companies' track, as well as travel priority over freight trains.

However, outside of the Northeast Corridor and a few states that invested in modernizing passenger rail routes within their jurisdictions, there was limited investment in the U.S. passenger rail system infrastructure or capacity. Regular federal appropriations were designated for Amtrak's capital

needs and to cover operating deficits, and long-term infrastructure and investment planning was subsequently difficult.

The 1980s brought forth several studies of potential, “emerging,” high-speed passenger rail corridors and the emergence of states as leading drivers behind the planning for and development of high-speed rail services. Several states formed public-private partnerships to build and operate intercity high-speed rail systems. Since the 1980s, however, in the face of the need for continuing federal subsidies, Amtrak has continually faced political challenges to its survival. In spite of the fact that, since 1997, ridership on Amtrak has grown faster than all other major modes of travel, after a \$700 million subsidy in 2005, it again faced elimination of its operating subsidies in the 2006 administration budget.

A New Vision for Passenger Rail

In early 2009, President Barack Obama’s administration proposed “[a] combination of express and regional high-speed corridors, evolving from upgraded, reliable intercity passenger rail service.” It proposed a “down payment” of \$8 billion in American Recovery and Reinvestment Act of 2009 funding and an additional \$2 billion in annual appropriations to be allocated to completing individual “ready to go” passenger rail projects, and entering into cooperative agreements with states, or groups of states, to develop entire portions of corridors having completed corridor plans and environmental documentation.

Immediately following this announcement, the Federal Railroad Administration (FRA) published “The High-Speed Rail Strategic Plan” and launched the High-Speed Intercity Passenger Rail Program (HSIPR) to make strategic investments in a network of passenger-rail corridors across the country. Objectives of HSIPR include the following:

- Build new high-speed corridors that expand and improve passenger transportation in their service areas
- Upgrade existing intercity passenger rail corridors to improve reliability, speed, and service frequency
- Lay the groundwork for future high-speed rail services through corridor and state planning efforts

Passenger Rail Investment and Improvement Act of 2008

Recognizing that high-speed and intercity passenger rail development would be a critical element of American economic growth and competitiveness, Congress passed significant legislation creating rail planning, development, and safety programs. The fundamental notion behind this new legislation was that passenger rail should be prioritized in federal and state planning and funding processes, alongside other transportation modes, in order to provide travelers with transportation alternatives over differing geographic scales.

The fiscal year 2008 Appropriations Act established a new intercity passenger rail state grant program (Capital Assistance to States-Intercity Passenger Rail Service) that provided \$30 million in competitively allocated funding to states that was contingent on a 50 percent nonfederal match. Up to 10 percent of the grant could be used for rail corridor planning projects.

The Rail Safety Improvement Act of 2008 (RSIA) reauthorized and augmented the FRA’s safety programs. Notably, the act required that all Class I railroad carriers and all regularly provided intercity or commuter rail passenger services implement positive train control systems no later than 2015. Positive train control systems comprise onboard automation to ensure train separation or collision avoidance, line speed enforcement, temporary speed restrictions, and rail worker wayside safety. This requirement provides the necessary rail traffic control to accommodate passenger trains traveling at significantly higher speeds than are presently achievable on shared infrastructure.

Finally, aside from reauthorizing Amtrak, the Passenger Rail Investment and Improvement Act of 2008 (PRIIA) revamped the federal-state partnership by requiring that Amtrak and the states develop a uniform cost structure for high-speed and short-distance (750 miles or less) routes outside the Northeast Corridor. It also established new high-speed and intercity passenger rail capital-improvement grant programs.

Under the Intercity Passenger Rail Service Corridor Capital Assistance (Section 301) program, states (including the District of Columbia), groups of states, interstate compacts, and state-established public intercity passenger rail agencies may apply for grants to pay for up to 80 percent of capital

projects designed to improve intercity passenger rail service. Importantly, eligible projects must be contained in a State Rail Plan.

The High-Speed Rail Corridor Development (Section 501) program is similar to Section 301 but is restricted to projects intended to develop federally designated high-speed rail corridors. Amtrak is also eligible to apply for this funding. Congestion Grants (Section 302) authorizes grants to states or to Amtrak (in cooperation with states) for financing of up to 80 percent of the capital costs of facilities, infrastructure, and equipment for high-priority rail corridor projects necessary to reduce congestion or facilitate intercity passenger rail ridership growth. Finally, Public-Private High-Speed Rail Concepts (Section 502) encourages public-private rail system development projects along federally designated high-speed rail corridors or Amtrak's Northeast Corridor.

PRIIA requires that states develop a State Rail Plan in order to be eligible for grant funding under these programs. It also requires that the U.S. Department of Transportation (USDOT) develop a National Rail Plan that is consistent with approved State Rail Plans. According to the High-Speed Rail Strategic Plan, the National Rail Plan "outlines national rail policies and priorities to promote an integrated, cohesive, efficient, and optimized rail system for the movement of goods and people."

National Rail Plan

Responding to the PRIIA requirement, the FRA in 2009 published a "Preliminary National Rail Plan" outlining the approach to be used for developing the National Rail Plan and policies to improve the U.S. transportation system consistent with the USDOT's overall strategic goals of improving safety; fostering livable communities; increasing the nation's economic competitiveness; and promoting sustainable, integrated, multimodal transportation. It recognizes the importance of the national rail system to the economic vitality of the United States, and the potential for passenger rail to contribute significantly to future growth. At the same time, though, it recognizes that passenger rail is dependent on privately owned infrastructure and that the private sector will play an important role in the success of any future passenger rail development.

Through the identification of projects of national significance, the National Rail Plan will be focused on increasing passenger and freight rail performance

by improving national transportation system performance. In order for this to be realized, rail must be better integrated with other modes of transportation to form a more complementary transportation system. The National Rail Plan proposes strategic investments in a high-speed intercity passenger rail network yielding "tangible benefits to intercity rail infrastructure, equipment, performance, and intermodal connections." In a 2010 progress report, it refines its vision by proposing a network of high-speed passenger rail corridors tiered according to geography and train speed.

The backbone of the national passenger rails system, core express corridors would connect large urban areas up to 500 miles apart with trains traveling 125 miles per hour (mph) to 250 mph with travel times ranging from two to three hours. These routes would be run on dedicated, electrified, publicly owned tracks. Operating between midsized urban areas, regional corridors would provide frequent 90-mph to 125-mph service on a mix of dedicated and shared (with freight rail) track. These routes could connect core express corridors. Emerging/feeder routes would connect regional urban areas at speeds up to 90 mph. These routes could connect to both core express and/or regional corridors, providing less densely populated or more distant areas with access to the national transportation network. As of this writing, the National Rail Plan has not been finalized.

State Rail Plans

Perhaps the most important requirement of PRIIA is the requirement that states develop formal plans that include passenger rail projects seeking capital project funding under the act. In 2012, the FRA issued process and content guidance to states for the development or update of their rail plans, emphasizing the requirement that any capital projects funded under Sections 301, 302, or 501 must be contained in the state rail plans of the applicant states.

PRIIA defines the following four primary responsibilities for states in rail planning:

- Establishing a state authority to develop the State Rail Plan to establish priorities and implementation strategies and serve as the basis for federal and state rail investment
- Coordinating with statewide and metropolitan area transportation planning agencies

- Involving public and private stakeholders—including all freight and passenger rail carriers, transit authorities, and other entities interested in improving statewide rail services and multimodal integration—in the plan development process
- Coordinating with neighboring states on common corridors

It also outlines the following role for the federal government in state rail plans:

- Establishing minimum content requirements and a recommended format for plan preparation, update, and submission
- Offering cooperative funding agreements for the completion of state rail plans and other planning activities

- Coordinating state rail plans with national and multistate rail planning efforts
- Developing analytic tools that can be used by states and other stakeholders to develop state rail plans or other planning documents

All of the contiguous 48 states and Alaska have drafted state rail plans.

A Bright Future for U.S. Passenger Rail?

The initial PRIIA grant programs were enormously successful, demonstrating not only a renaissance in interest in passenger rail in the United States but also a willingness of states to work with each other and with the federal government and private rail companies toward the expansion and improvement of intercity passenger rail. The federal



The Rajdhani Express was introduced in 1969 to provide fast connections from New Delhi to the capital cities of various states in India. Passenger train service in India has since expanded rapidly, especially over the past decade. The West Central Railway became operational in 2004 and is one of 17 new railway zones of Indian Railways, with its headquarters at Jabalpur.

government received \$102 billion in preapplications and \$55 billion in final applications for the \$8 billion available funding from ARRA. In addition to funding 38 projects across 31 states, the federal government succeeded in creating a long pipeline of passenger-rail projects awaiting future funding opportunities.

Many major projects were undertaken under PRIIA funding, including a nearly \$1 billion investment to upgrade some of the most heavily utilized segments of the Northeast Corridor, Amtrak's most successful. Notable, as well as controversial, was the nearly \$4 billion to fund environmental and engineering studies for the first segment of a 220-mph high-speed rail system through the Central Valley of California planned to link Los Angeles and San Francisco.

Following this success, the second Obama administration called for a six-year, \$53 billion spending plan. Congressional funding of this continuing initiative is still uncertain as of this writing. Furthermore, no source of funding outside year-to-year congressional budget allocations has been identified to secure Amtrak's long-term survival or to enable it to make the sort of investment decisions necessary to realize its full future potential.

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See also: High Speed Rail, Policy and Planning of; Rail Transit Planning, U.S.; Rail Transit Planning, Worldwide; Railroad Industry, Economics of; Transportation Policies, North American.

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Rails-to-Trails Programs

There are tens of thousands of miles of public recreational trails in the United States, with the number increasing annually. The wide variety of trail uses include remote hiking and camping, snowmobiling in northern forests, and bicycle commuting in the nation's dense metropolitan areas. Rich hierarchical networks of trails have emerged over the past five decades through federally facilitated public, private, and not-for-profit (NFP) collaborations. "Rails-to-trail"—the reuse and multiuse of abandoned railroad corridors—is an increasingly important, specialized component of this process.

Following World War II, the nation faced many challenges in its transformation to a peacetime economy. One of these was the escalating gap between the supply and demand for outdoor recreation. The gap was a result of the steep population growth during the baby boom, rapidly increasing mobility from auto ownership, the construction of the interstate highway system, reduction in the workweek, increased disposable income, and the accelerating open-space loss from suburban sprawl.

In 1958, Congress established the Outdoor Recreation Resources Review Commission (ORRRC) to conduct a nationwide inventory and analysis of resources and opportunities, with trend forecasts for 1976 and 2000. In addition to federal land management agencies, all states participated. The ORRRC analysis was an innovative use of multidiscipline, quantitative social science. It legitimized outdoor recreation as an important topic in legislative and administrative decision making and a new field of academic study. ORRRC recommendations included the following: creating a systematic resource classification system for facility planning

and management; improving collaboration between federal, state, and local governments, with “citizens and private enterprise continuing to play the most important role;” and the need for innovative funding approaches.

In 1965, Congress passed the Land and Water Conservation Fund Act (LWCF). This legislation allowed a portion of the federal income from offshore oil and gas leasing to be used for statewide, comprehensive outdoor-recreation planning. Based on these plans and a state-established system for project prioritization, states could apply for 50 percent matching funds for state and local governments to acquire land rights, and undertake conservation-related restoration and development projects, including trails.

In 1966, the Bureau of Outdoor Recreation (BOR) released *Trails for America*, a nontechnical report advocating a comprehensive national-state-local program. This became the basis for the National Trail System Act of 1968 (NTSA), which authorized a National Trails System (NTS) with three categories: scenic, recreation (“reasonably accessible to urban areas”), and connecting and side trails. A fourth category, historic, was added in 1978. NTSA also encouraged states to include complementary statewide, regional, and local trails in their plans and applications for LWCF funding, thus, over time, generating integrated systems. Today, NTS trails exceed 50,000 miles.

Trail planners in this period looked closely at joint-use opportunities involving existing utility corridors, such as railroads, pipelines, and electric transmission lines. These presented major challenges because of their private corporate ownership, as well as associated safety and liability issues. Although utility corridors were growing, construction of the interstate highway system had significant negative economic impacts on the nation’s railroads, as trucking rapidly captured freight market share.

Railroads, with extensive public assistance, had played a major role in the economic development of the country from the mid-1850s through World War II. Private rail corporations acquired extensive networks of real property interests by multiple means. Some private lands were purchased outright, either in fee simple (full title) or right-of-way (ROW), which provides private corporate access for construction, operations, and maintenance. In much of the Midwest and west, the federal government had



Part of Atlanta, Georgia’s, BeltLine Trail undergoes construction in 2012. This rail-based trail, which will eventually encircle the city, is part of a comprehensive greenway program that includes parks, transit, and neighborhood redevelopment.

originally acquired land by treaty or war. Various programs, such as homesteading, were undertaken to transfer title to the private sector.

Railroads were critical for this transformation. As incentive, they were frequently granted fee-simple title or an ROW for their lines through public lands. In some regions, they were also given title to adjacent land for development or sale. ROWs were granted for routes across federal lands, such as national forests, and into national parks, where rail corporations were encouraged to build and operate tourist lodges. Rail lines were essential for mining on federal lands, too. U.S. railroad mileage peaked in 1900 at over 250,000 miles; today, the total is under 100,000 miles.

By the 1970s, there were numerous railroad bankruptcies and increasing pressure by rail corporations to abandon unprofitable routes. The Railroad Revitalization and Regulatory Reform Act of 1976

(4Rs) was part of a reform initiative to encourage private enterprise through regulatory reduction. The 4Rs eliminated the Interstate Commerce Commission and created the Surface Transportation Board (STB) within the U.S. Department of Transportation (USDOT) to regulate railroads, including abandonments, for which rail corporations must apply. The STB decides those requests based solely on economic impact, weighing the loss of service to local communities and businesses versus the ability of the rail corporation to continue profitable operation and grow services in other geographic sectors of its system.

Rails-to-Trails

If abandonment is approved, STB regulations provide opportunities to transform all or part of the line to public trail use. "Rail banking" is an option where the line is on an ROW and the rail corporation has an interest in potentially reactivating the line at some future date, for the reopening of a mine, for example. If an agreement is reached between the corporation and trail reuse intervener, a government agency or state-approved NFP, the corporation may salvage rails and ties and gain tax advantages through charitable deductions and subsequent reductions in property taxes. The trail ROW receiver assumes liability and structural maintenance responsibilities. The rail corporation retains "first right of refusal" to reacquire the ROW if it comes up for sale at a future date.

Where the railroad holds fee simple ownership and is not interested in banking, there is an alternative approach. Following the abandonment approval, trail conversion interveners have 180 days to negotiate with the corporation for title transfer. If no trail agreement is reached, the property can be sold on the open market for another use.

The 4Rs regulatory opportunity window for rail-to-trail conversion was complicated by the need for careful monitoring of the railroad regulatory abandonment proceedings in Washington, D.C.; by shortfalls of funds; and by multiyear waiting lists for the state-approved LWCF funding. By the 1980s, under STB's 4Rs, up to 10,000 miles of rail were being abandoned each year, little of which was being converted to trail use.

In 1986, the Rails-to-Trails Conservancy (RTC) was created in Washington, D.C., to focus on this specific latent opportunity. The RTC, working with

other environmental groups, has been particularly effective in influencing federal legislation. The 1988 National Trail System Improvement Act includes a section under the heading "Abandoned Railroad Grants; Retention of Rights" that closes a significant loophole. When the STB approves abandonment, if the route is an ROW on federal land, the ROW automatically reverts to federal ownership. Where this route occurs outside an active federal land management unit, such as a national forest, it can be transferred directly to an approved trail agency or NFP. Where trail use is not feasible, the federal property rights may be sold, with the proceeds going to the LWCF.

A major funding success was achieved in the drafting of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). This law created two new programs operated by the Federal Highway Administration (FHWA). The Transportation Enhancement (TE) Program was allocated 10 percent of all surface transportation funds, to be utilized for 12 types of construction-only projects including pedestrian and bicycle facilities, and "conversion of abandoned railway corridors into trails." TE funds are allocated to state transportation departments.

In metropolitan areas, trail projects proceed through the Metropolitan Planning Organization's Transportation Improvement Program (TIP). In nonmetropolitan areas, they are approved by the state TIP. Approximately 8 percent of TE funds have been used for rail trails. ISTEA also created the Recreational Trails Program (RTP). This sends Federal-Aid Highway Program funds collected from non-highway-use fuel taxes, such as from snowmobiles, back to the states.

Paralleling the LCWF, most states administer RTP funds through a park or natural resources agency with a citizen trail advisory committee. A minimum of 30 percent of RTP-funded projects must allow motorized uses. TE funding has become more highly controversial in each subsequent transportation act. This is because Congress has not increased the federal fuel tax to keep pace with the rapidly rising costs of maintaining or replacing the aging interstate highway system.

For three decades, the RTC-led rails-to-trails movement has been a very successful component of larger trail and greenway initiatives. There are now over 20,000 miles of rails-to-trails completed, with 9,000 miles in process. In 2001, President George

W. Bush issued Executive Order 13195, "Trails for America in the 21st Century." It created the Federal Interagency Council on Trails to coordinate all federally assisted trail programs.

The FHWA has established a Trails and Enhancement unit in the Office of Planning, Environment, and Realty to facilitate federal rails-to-trails-related programs and the 50 RTP state programs. It provides a central clearing house for program data, technical assistance information, and educational resources. The FHWA's planning and design guidelines differentiates between "rail trails," which are in abandoned rail corridors, and "rails-with-trails" in which the trail is adjacent to an active rail line. Rail-based trails play a significant role in achieving the goals of the early ORRRC report. Examples range from Nebraska's 319-mile "Cowboy Trail" rail-bank corridor to the evolving "Atlanta BeltLine" trail, which will eventually circle the city. The latter project is part of a comprehensive greenway program that includes parks, transit, and neighborhood redevelopment.

Railroads expanded rapidly throughout the world in the 19th and 20th centuries. Today, the rails-to-trails movement is under way in many countries in addition to the United States. Each is evolving a unique set of institutional, economic, and collaborative approaches to this important recreational and environmental opportunity arena.

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See Also: Bikeways/Bike Lanes, Road Design Issues of; Greenways; Intermodal Surface Transportation Efficiency Act; Recreational Travel; Urban Trail Systems.

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Recreational Travel

Over the last 100 years, a general rise in individual wealth, improvement in living standards, and related increase in leisure time has come with an associated rise in travel for recreational purposes. Such travel can be divided into two categories: international and domestic. The United Nations World Tourism Organization (UNWTO) reports that international arrivals worldwide have more than doubled since 1990, rising to 940 million in 2010. The World Travel and Tourism Council (WTTC) indicates that these figures do not take into account domestic tourism, which is estimated to generate up to 10 times more arrivals than international tourism. The U.S. Travel Association (USTA) reported that direct spending on leisure travel by domestic and international travelers totaled \$564 billion in 2011.

Travel is fundamental to accessing recreation opportunities. Therefore, tourism would not exist without transportation; it provides the connectivity between home origin and leisure activity destination. Recreational travel involves a household's discretionary budget. This means that there are a number of factors that may influence the decision to make a trip. Some of these are the competing demands on the time available to travel, the perceived value of the journey, and the availability of satisfactory services to meet the travelers' needs. In addition, although people's potential leisure time may have increased, there may also be limitations on its availability because of barriers such as employment commitments and restrictive vacation windows.

Recent research on European Union leisure travel has provided valuable insights into the factors that can influence recreational travel choices. The research found that people are more likely to make trips within their own country, and that these journeys tend to be by automobile. A report on global travel trends, meanwhile, found that people are taking shorter breaks, flying rather than taking their car when they travel internationally, and that Europeans are increasingly choosing long-haul destinations, such as the Americas and the Asia Pacific region.

Individual traveler demographics, travel companion arrangements, traveler preferences and perceptions, and destination characteristics are also found to be important to the leisure travel choices made.

As noted above, an important aspect of individual sociodemographics is available disposable income. For example, in the United States and United Kingdom (UK), as the recession of recent years took hold, household incomes and budgets were affected, spawning a greater propensity for vacationing at home, leading to the coining of the term *staycation*.

Exploring motivations for recreational travel reveals numerous reasons for deciding to make a trip. For example, looking at domestic travel and taking the United States as an illustration, the USTA reports that in 2011 the top leisure travel activities for domestic travelers were (1) visiting relatives, (2) shopping, (3) visiting friends, (4) fine dining, and (5) beaches.

In terms of international travel, the UNWTO reports on worldwide arrivals by purpose of visit. This data indicate that the main activity categories were, respectively, leisure/recreation/holidays and visiting friends and relatives/health/religion. Visiting friends and relatives, according to the WTTC, represents up to one-third of all arrivals for some large developed markets, pointing to the importance of maintaining cultural and ethnic links when traveling internationally during leisure time.

Recent research has explored the relational nature of recreational travel further. One research team highlights the complexity of leisure travel, indicating that it is dependent on a combination of other people's participation, characteristics of the destination, and, at the same time, linkages between activities and people's social networks.

Social and Economic Significance

The social and economic significance of recreational travel is manifold. On the positive side, it supports local jobs, justifies investment in infrastructure, and promotes cultural asset preservation. Negatively, it contributes to traffic congestion and other environmental degradation effects, can generate economic benefits that are not reinvested locally (for example, all-inclusive resorts), and can portray the population of the host location in purely subservient roles.

Looking at the transportation-related impacts of recreational travel in more detail, the positive effects of infrastructure development—such as road improvements, airport development, and increased transport connectivity structures—are not only benefits to inbound tourists but also to the wider

local community. However, such improvements come at a price, which is usually borne by the government of the host community.

In addition, large-scale transportation projects can involve extensive land acquisition (including compulsory purchase of local homes), resulting in severing of communities, and broad environmental effects (such as increased noise, revision of water and sewerage routings, and other impacts on natural resources).

It also should be noted that the tendency for domestic leisure trips to be made by car has implications for sustainability. For example, in the UK, there has been an increasing demand for leisure trips that are mainly made by car. Given the concern about environmental impacts of automobile use, there is an imperative for visitor attractions to encourage modal shift to more sustainable options.

Turning to the supply of recreational travel services, the distribution of travel information and booking processes has been undergoing considerable change in the past couple of decades. In the past, travel agents and airline distribution systems were the dominant channels of sale in the area of leisure travel products and services. As Internet access has become almost ubiquitous, the ways in which people access information and then go on to book leisure travel has also evolved to reflect the use of new media.

Not only do an increasing number of people book their leisure travel directly on the Web, but research also suggests that people are tending to base leisure travel decisions more and more on what friends say on social media or even what strangers post in reviews on various travel sites. It may be that the trend toward decision making that involves others' experiences relates to an inclination to seeking more authentic and individualized experiences. Against this background, the cookie-cutter, packaged holiday may start to become a less viable solution for many, and suppliers will need to adapt to a much more tailored approach to satisfying traveler demand.

In the future, the rise in the middle class in emerging economies of Brazil, Russia, India, China and South Africa (the BRICS nations) will be increasingly important to the recreational travel market and, consequently, trip choice and patterns. For example, the UNWTO reports that, for the last decade, China has been the fastest-growing tourism source market in the world.

Some of the other themes that will also be important in travel include medical tourism (for example, people traveling out of country to have plastic surgery and other medical procedures abroad, as specialist operators offer options to combine surgery and holidays), the aging population (many of whom will have prior experience of leisure travel and disposable incomes that will shape their choices of trip/destination), and “slow travel” (that is, people choosing to savor the experience of travel by lingering more and racing less from place to place).

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See Also: Business Travel; International Air Passenger Transport; International Travel; Noncommuter Travel; Tourism; Travel by Persons; Travel Choice.

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Recreational Vehicles

A recreational vehicle (RV) combines transportation and temporary living quarters for travel, recreation, and camping into one package. RVs also reflect historical, social, and cultural trends, as well as planning and policy issues in transportation. The U.S. Department of Transportation (USDOT) enforces regulations for RVs above 10,000 pounds under Federal Motor Carrier Safety Regulations, while the states license RVs and their drivers.

In 2011, the Recreation Vehicle Industry Association (RVIA) commissioned the University of Michigan to conduct a study of RV ownership. The study numbers revealed that RV ownership in the United States has climbed to record levels with approximately 8.9 million households owning an RV in 2011. The University of Michigan study revealed that the RV buying power and habits of the enormous baby boomer generation is a key factor behind the RV ownership upswing as well as climbing ownership figures among younger and older buyers. RV ownership numbers extend across a 40-year span from age 35 to 75. The study found that the typical RV owner is 48 years old, married, with an annual household income higher than the median for all other households. RV owners are likely to own their homes and spend disposable income on traveling an average of three weeks a year.

From Autos to RVs

Outdoor enthusiasts quickly recognized the camping potential of recreational vehicles. The first RV, Pierce-Arrow’s Touring Landau, debuted at Madison Square Garden in 1910 and featured a back seat that folded into a bed, a chamber pot, and a sink that folded down from the back of the chauffeur’s seat. Los Angeles Trailer Works and Auto-Kamp Trailers also rolled models off the assembly line in 1910, and soon dozens of companies produced what were then called auto campers.

As automobiles became more reliable, people traveled more often, and travelers using more campers demanded more campsites. From 1913 to 1924, Thomas Edison, Henry Ford, Harvey Firestone, and naturalist John Burroughs traveled in car caravans on annual camping trips. Although they slept in tents, they brought along a custom Lincoln truck outfitted as a camp kitchen. The radio and press covered their adventures and they inspired ordinary people to go camping. Campers, called “tin can tourists” because they heated tin cans of food on gasoline stoves alongside the road, founded the first camping club in the United States. In 1919, they held their first rally in Florida, and by the mid-1900s their club had grown to 150,000 members. The club had an initiation, a secret handshake, and an official song, “The More We Get Together.”

During the Depression some people spent between \$500 to \$1,000 on travel trailers to use as an inexpensive home. World War II rationing

stopped consumers from buying RVs, but some companies manufactured units to serve as mobile hospitals, prisoner transports, and morgues.

After World War II, veterans and their young families searching for inexpensive vacations combined with an extensive new interstate highway system to stimulate a second RV boom lasting through the 1960s. In the late 1950s, motorized RVs gained in popularity, but they were still an expensive luxury and less popular than trailers. Winnebago transformed the market in 1967 when the company began mass-producing what it called “America’s first family of motor homes,” five models ranging from 16 to 27 feet long and selling for about \$5,000.

In 1967, CBS News correspondent Charles Kuralt also recaptured the romance of life on the road when he began reporting his *On the Road* series. Over the next 25 years, he wore out several motor homes and covered more than a million miles.

According to Al Hesselbart, historian of the RV/MH (motor home) Hall of Fame in Elkhart, Indiana, the market changed again as RVs became more sophisticated. Modern RV amenities are limited only by budgets and they feature convection ovens, microwaves, washers and dryers, king-size beds, heated baths and showers, and satellite dishes. Sophisticated and state-of-the-art RVs attracted a new breed of adventurer, less interested in camping and more in destinations like Disney World, the national parks, and themed events.

There are more than 16,000 public and privately owned campgrounds across the United States. Public campground facilities tend to be simple but may be located amid great scenic beauty. Public lands are popular for hiking, fishing, whitewater rafting, and a variety of other outdoor recreational activities.

Privately owned RV parks and campgrounds are located near popular destinations, along tourist routes, and in metropolitan areas. They offer a variety of family activities, including swimming pools, game rooms, playgrounds, and snack bars. RV travelers seeking a resort atmosphere can choose from the growing number of luxury RV resorts that offer facilities like tennis courts, golf courses, and health spas.

Planning

Approximately 7.2 million RVs ply American roads, according to a University of Michigan study that the RIA commissioned in 2011. The RVIA

estimates there are at least 30 million RV enthusiasts nationwide, including RV renters. Many people rent an RV to try it out for traveling before they buy one. The U.S. Census of Retail Trade and the RV Rental Association (RVRA) estimated that the RV rental business is a \$350-million industry, with more than 460 RV rental establishments located across the country.

RVs are divided into two main categories: motor homes that are motorized, and towables that are pulled behind a car, van, or pickup. Type A motor homes are usually the largest and Type B motor homes or van campers are the smallest, with Type C motor homes falling in between. Types of towable RVs include folding camping trailers, expandable trailers, truck campers, conventional travel trailers, and fifth wheel travel trailers.

RVs are also divided into classes. Deemed the nicest motor home of the three main classes, the Class A is a motorized RV built on a special chassis designed specifically for motor homes. They are rectangular in shape and usually 30 to 40 feet long. Their large size accommodates the comforts of a house, including a full kitchen and bathroom and self-contained water and sanitation systems. They often feature washers and dryers and foldouts for extra space.

A motorized RV built on a van chassis, a Class B is usually called a “van conversion,” which at 17 to 19 feet long is much smaller than class A models. Living space and amenities are limited in conversion vans and they have portable chemical toilets instead of on-board sanitation systems. Some van conversions have pop-up roofs for additional standing room. The smaller size of a class B makes them easy to drive and some people use them as their regular vehicle as well as for camping.

Built on a truck chassis, a Class C motorized RV is a mid-grade RV, which at 20 to 21 feet long is bigger than a class B and smaller than a class A. They have more amenities than a Class B and fewer amenities than a class A, including self-contained water and sewage systems. Class C RVs have an overhang over the main cab that serves as an extra sleeping area, which compensates for their lack of a separate bedroom. Some class C RVs are designed with slide-outs for extra room when parked.

Bus conversions are buses ranging from home-made RVs converted from an old school bus to professional conversions made from diesel commercial bus liners that have been remade into recreational



Iconic American-made Airstream trailers park in a recreational vehicle (RV) park in the Netherlands in 2012. In 2011, a study found that RV ownership in the United States has reached a record 8.9 million households. There are also more than 12,000 RV-related businesses in the United States producing annual revenues of more than \$37.5 billion.

vehicles. Homemade bus conversions are bare-bones models with barely any amenities, while others feature the amenities of a Class A recreational vehicle.

Towable RVs come in different versions, including fifth wheel trailers, travel trailers, and pop-up trailers. They do not have a motor but instead are usually pulled behind a truck or car if they are small enough. They range from small to large, and from bare bones to full amenities.

RV Companies

Major RV products are motor homes, travel trailers, and folding or camping trailers. Motor homes and travel trailers each contribute one-third of industry revenue, while folding trailers account for about 10 percent of industry revenue. Some manufacturers make “park” models, basically small manufactured homes that require hookups and are designed to be only occasionally moved.

According to the Recreational Vehicle Manufacturing Report, the recreational manufacturing industry in the United States consists of about 900 companies, including Fleetwood RV, Thor Industries, Winnebago, Airstream, and Forest River, and

the top 50 travel trailer manufacturers generate more than 75 percent of industry revenue. There are more than 12,000 RV-related businesses in the United States producing annual revenues of more than \$37.5 billion.

Airstream, Elkhart, and the USDOT

Airstream, maker of luxury recreational vehicles based in Jackson Center, Ohio, is currently a division of Thor Industries and is the oldest manufacturer of recreational vehicles in the industry. Airstream presently manufactures nearly 2,000 trailers and motor homes a year. Airstream makes several models, including Sport, Flying Cloud, Eddie Bauer, and Classic Limited, as well as models for the European market.

In the early 1950s, Airstream company founder Wally Byam took groups of Airstream owners on trips to many parts of the world, creating an Airstream mystique that survives to this day. The Wally Byam Caravan Club formed in 1955 in Kentville, Nova Scotia, Canada, and later the club became the Wally Byam Caravan Club International. Club members still gather every summer, and hundreds

of local clubs hold rallies. Airstreams are still popular and there are over a dozen Airstream Parks across the United States.

More than 60 percent of recreational vehicles are made in Elkhart County, Indiana. Known as the “RV Capital of the United States,” Elkhart offers RV service, repairs, parts, and accessories to dealers, RV campgrounds, and rallies. Another 15 percent of RVs are built in Oregon and California.

The USDOT regulates RVs over 10,000 pounds under the Federal Motor Carrier Safety Regulations, which specify requirements about tires, rims, and load limits. The Department of Transportation allows states to decide licensing and lighting requirements, and regulations vary from state to state, although all of them require current vehicle licensing. A handful of states require commercial driver’s licenses (CDLs) to operate an RV, and more than a dozen require special permits to drive RVs that are over a specified weight or length.

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See Also: Recreational Travel; Scenic Roads and Parkways; Tourism; Travel Destinations; U.S. Department of Transportation; Vans.

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Regional Transit Agencies

The International Energy Agency has predicted that by 2035, there will be 1.7 billion vehicles traversing the world’s roads. Despite the ubiquity of cars, trucks, and recreational vehicles, many people in the

United States remain dependent on public transportation for getting to work and school and for doctor’s visits and essential shopping trips. Most of the passengers on buses run by various regional transit agencies are comprised of students, senior citizens, the disabled, and those who do not have their own vehicles. Passengers are disproportionately African American and Hispanic.

Each state and local authority has responsibility for managing its own public transportation services. State departments of transportation oversee all transportation services, and funding at that level must be authorized by state legislatures. Individual cities and towns provide approximately one-fourth of the budget for regional transit agencies. At the federal level, the Federal Transit Administration works with state and local governments on issues of regional transit. It has proven to be more economical from both the federal and local perspectives to fund regional projects rather than those that are entirely local, which are narrower in scope by definition.

According to the American Public Transportation Association (APTA), which has kept detailed reports of the public transportation sector since the beginning of the 20th century, using public transportation in the United States reduces annual levels of gasoline by the equivalent of 4.2 billion gallons. In addition to drastically reducing the amount of fossil fuels released into the environment, the very existence of public transportation saves Americans 796 million hours that would have been spent stuck in traffic jams. APTA reports that reducing traffic congestion through public transit saves \$16.8 billion each year.

Largest Regional Transit Agencies

The largest group of transit agencies operating in the United States is comprised of nonprofit agencies that function solely to meet the needs of specific groups such as the elderly or the disabled. However, the group most often associated with regional transit agencies (RTAs) in the mind of the public is made up of regional transit authorities. In 2012, there were 1,460 rural transit agencies and 786 urban transit agencies. It is the urban regional transit agencies that serve 98 percent of all passengers using public transportation.

The largest regional transit agency in the United States is the MTA (Metropolitan Transit Authority)

New York City Transit, which transported 3.3 billion passengers over 11.6 billion miles in 2012. Because the service links New York City with surrounding areas, it connects to other transit agencies in New Jersey and Connecticut. Together, these agencies served 4.1 billion passengers and logged 21.3 billion passenger miles in 2012.

The other largest RTAs that serve urban areas throughout the United States are Chicago Transit Authority, Los Angeles County Metropolitan Transportation Authority, Washington (D.C.) Metropolitan Area Transit Authority, Massachusetts Bay Transportation Authority, Southeastern Pennsylvania Transportation Authority, New Jersey Transit Corporation, San Francisco Municipal Railway, Metropolitan Atlanta Rapid Transit Authority, MTA Bus Company (New York City), King County DOT (Seattle), San Francisco Bay Area Rapid Transit District, Tri-County Metropolitan Transportation District of Oregon, Maryland Transit Administration, and MTA Long Island Rail Road (New York City).

Special Needs

In 1968, Congress passed the Architectural Barriers Act of 1968 and followed it up in 1973 with the Rehabilitation Act. Both bills guaranteed that public facilities be made accessible to disabled Americans. In 1977, the Department of Health, Education, and Welfare issued guidelines supplementing those actions by requiring that all state and local bodies receiving federal transportation grants make all programs and jobs accessible to the disabled population.

In 1990, President George H. W. Bush signed the Americans with Disabilities Act (ADA) into law. Among other things, ADA mandated access to public transportation for people with physical disabilities. The responsibilities of RTAs were spelled out by the U.S. Department of Transportation (USDOT) in accordance with ADA, stipulating that transportation agencies must offer complementary paratransit services to disabled Americans not able to take advantage of the fixed-route system provided by the RTA. Subsequently, systems began offering lifts and other aids to meet the needs of disabled passengers. In 1990, when ADA was signed, there were 68 million passenger trips on demand services being offered to Americans with special needs. By 2010, the number of those services had climbed to 190 million.

In addition to offering assistance for the elderly, RTAs are also equipping buses with bike racks to meet the needs of those who travel to and from transit stations by bicycle. In 2001, only 32 percent of buses were equipped with bike racks. That number rose to 74 percent in 2011.

Budget Problems

According to a 2009 report issued by Transportation for America, in 2008 Americans took approximately 10.7 billion trips on some form of public transportation. That amounted to an increase of 38 percent since 1995. Despite this demonstrated need for public transportation, only 18 cents out of every federal dollar spent on the transportation sector is earmarked for public transportation. Thus, the burden falls on RTAs to provide the funds needed to remain in operation.

When the United States experienced a major economic downturn in the early 21st century, RTAs were forced to take action. That action frequently included drastic cutbacks in service, laying off of workers and raising fares at a time when many riders were barely getting by. Since federal funds generally go toward essential construction and equipment, little is done to modernize systems.

The Massachusetts Bay Transit Authority stands as only one example of an RTA that has been affected by 21st-century budget problems. With 15 regional transit authorities operating under the Massachusetts Bay Transit Authority, the state of Massachusetts has one of the most highly developed RTAs in the United States, but even that system fails to reach certain areas within the state. Even passengers who have access to the service do not always have their needs met. Passengers who ride the Berkshire Regional Transit Authority, for instance, experience long waits and frequent transfers, and routes are often indirect. It may take three times as long to arrive at a destination as it would take to travel the same distance by car.

In 2013, the state legislature banned the practice of operating the system with loans. Governor Deval Patrick proposed a \$100 million annual allotment to keep buses within the system running. Another \$12 million was earmarked for improvements. Those funds were not considered sufficient to keep the system financially healthy. Recent budget cuts had already led to the elimination of

routes and cuts in service, including no service after 7 p.m. and elimination of all Sunday service.

In 2008, funding for RTAs increased in response to passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Additional funds were allotted as part of President Barack Obama's American Recovery and Reinvestment Act in 2009. The Federal Transit Administration (FTA) continues to dispense federal assistance, grants, and loans. In 2012, for instance, out of a total of \$12.8 billion, FTA dispensed \$103 million in funds to metropolitan and state planning agencies, \$982 million in funds to buses and bus facilities, and \$5.7 billion in funds to urban areas. In addition to those funds, FTA dispensed 1,116 grants to urbanized areas, 470 to buses and bus facilities, and 45 to metropolitan and state planning for transit projects.

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See Also: American Public Transportation Association; Americans with Disabilities Act of 1990; Federal Transit Administration; Rail Transit Planning, U.S.; Subway Systems; Surface Transportation Assistance Acts of 1978 and 1982; U.S. Department of Transportation.

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Regional Transportation Planning

Regional transportation planning is an interstate or intrastate collaboration among various local, state, and federal agencies to identify and analyze transportation needs of a region and to prepare a guide to the long-range development of the region's transportation system. This transportation plan covers all modes of transport including automobile, transit, bicycle, pedestrian, railroad, freight, and intermodal movements. The first regional transportation plan dates back to 1919 and 1920 when the Detroit Rapid Transit System recommended a multimodal system.

Other regions developed their own transportation plans during the 1920s, often as part of a larger urban planning effort. However, it was the Federal-Aid Highway Act of 1962 that required metropolitan regions to adopt long-range transportation plans in order to qualify for federal funds that shaped regional transportation planning across the nation. For the next 50 years, federal legislation and initiatives fostered integrated regional transportation planning through a variety of regulations and strategies.

Regional transportation planning encompasses a geographic area larger than the borders of local governments but one that is defined by common social, economic, political, cultural, and natural resources, and transportation characteristics. The agencies charged with this planning throughout the United States are sometimes voluntary associations and sometimes councils or commissions authorized by state legislatures. Regardless of the nature of the planning agency, the purpose of the transportation plan is to provide a lucid view of the region's transportation goals, policies, and strategies developed with an understanding of the existing system and financial constraints. The plan may also include an assessment of the current modes of transportation, predictions of future transportation needs, and recommendations for specific actions to address problems and meet the region's mobility and accessibility needs.

The Origins of Regional Transportation Planning

Nearly two decades before the Detroit Rapid Transit System offered the first official regional

transportation plan, the Massachusetts legislature created the Boston Metropolitan Improvement Commission, the first regional planning agency with planning powers. Plans for railroads and roads were among the commission's proposals. The Plan of Chicago, financed by the Commercial Club of Chicago, a private organization, in 1909, included regional proposals for transportation in its plan, which envisioned Chicago in a regional context.

For a brief period from 1913 to 1915, Pennsylvania's Suburban Metropolitan Planning Commission was authorized to create a comprehensive plan, including highways and parkways, for Philadelphia and a 25 mile radius around the city. The most famous of these regional plans was the Regional Plan for New York and Environs, financed by the Russell Sage Foundation and prepared by an advisory committee. The eight-volume document, begun in 1921 and completed in 1929, included regional proposals for transportation for a 5,528-square-mile area with 500 incorporated entities in New York, New Jersey, and Connecticut.

Other planning commissions with visions of regional networks were established in sites across the country during the 1920s. But while transportation planning was included in the work of these groups, it was only one part of their larger responsibilities. It would take another four decades and an expansive highway program to make regional transportation planning a national priority.

The Federal Aid Highway Act of 1962 and Beyond

Transportation historians cite the passage of the Federal Aid Highway Act of 1962 as the beginning of formal regional transportation planning in the United States. President John F. Kennedy signed the bill on October 23, 1962, six months after he had addressed Congress in a speech that stressed the role of multimodal transportation in domestic well-being and international competition. Among other provisions, this legislation required the establishment of a Metropolitan Planning Organization (MPO) in all areas of the United States with a population that exceeded 50,000. The focus was on the urban region rather than merely the city proper.

MPOs were to conduct a transportation planning process that was "continuing, comprehensive, and cooperative" in order to receive federal highway and transit funding. "Cooperative" referred not

only to federal, state, and local governments working together to make and implement transportation plans but also to the cooperation of various governmental agencies at all levels. "Continuing" referenced the need for periodic evaluation and updates. "Comprehensive" particularly included the elements of the planning process for which inventories and analyses were required: economic factors; population; land use; transportation facilities, including those for mass transportation; travel patterns; terminal and transfer facilities; traffic control features; zoning ordinances, subdivision regulations, building codes, and the like; financial resources; and social and community-value factors, such as preservation of open space, parks, and recreational facilities; preservation of historical sites and buildings; environmental amenities; and aesthetics.

New regulations in the 1970s required each MPO to produce a long-range Regional Transportation Plan (RTP) based on projecting demographic, housing, employment, and other conditions at least 20 years into the future and a short-range Transportation Improvement Program (TIP) that provided a schedule of active projects. (See specific entries on these topics for further details.) The planning was required to include public involvement, financial feasibility, conformity with air quality standards, consideration of the environment, and intermodal coordination.

With 90 percent federal funding for interstate highway projects at stake, states had considerable incentive to establish MPOs. Some states had a single MPO; others had many. California, for example had 10 at the end of 1962. For further information on these entities and their functions see the entry for Metropolitan Planning Organizations (MPOs).

From the beginning, not all regional planning organizations were MPOs. The state of Washington, for example, distinguishes between MPOs, which are mandated and financed by federal funds, and regional transportation planning organizations, which are authorized and funded by the state and may include both urban and rural groups. In some rural areas, no official group is designated to focus on the area's transportation plans; in others, the state or a rural planning organization does so.

Until the passage of the the Transportation Equity Act for the 21st Century (TEA-21), federal legislation did not require local participation in the transportation planning process outside urban

areas. TEA-21 awarded a greater share of formula funds to rural public transportation.

In 1999, the U.S. Department of Transportation announced the Rural Transportation Initiative with the stated purpose of increasing the capacity of rural America to play a more integral role in the planning and decision making that shape transportation systems. In 2013, 30 states have some form of rural transportation planning organization. They may be called rural transportation planning organizations (RTPOs) rural planning organizations (RPOs), regional planning affiliations, regional transportation planning agencies, or simply general purpose councils of governments or Regional Planning Commissions that have a rural transportation planning program.

For the first time in federal legislation, Moving Ahead for Progress in the 21st Century (MAP-21), passed in 2012, included a definition of the basic structure and responsibilities of RTPOs. The statute requires RTPOs to have a lead planning agency that serves as the fiscal and administrative agent and provides planning staff support. Designated responsibilities of RTPOs include developing rural regional long-range transportation plans; creating short-range transportation improvement programs; conducting public outreach; and coordinating transportation with other relevant planning areas.

To a greater degree than any other federal program, transportation has a historically strong, consistently funded planning process. Since the Federal Aid Highway Act of 1962, the adoption of long-range transportation for multiple modes of transportation has been encouraged. While much regional transportation planning is led by MPOs, other stakeholders are also involved in the process. In recent years, rural areas have been increasingly part of the process. Businesses, community groups, environmental organizations, and private citizens have an opportunity to be involved in transportation planning through a public participatory process.

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See also: Metropolitan Planning Organizations; Moving Ahead for Progress in the 21st Century Act; Regional Transportation Plans; Transportation Equity Act for the Twenty-First Century; Transportation Improvement Programs.

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Regional Transportation Planning Organizations

Although regional transportation planning organizations (RTPOs) go by a variety of names, including metropolitan planning organizations (MPOs) and councils of government (COGs), they all serve as a primary transportation planning agency for metropolitan areas throughout the United States. RTPOs are the channel through which federal transportation funds are allocated, and they may also serve a wide variety of other functions.

For more than four decades, RTPOs have been responsible for continuing, comprehensive, and cooperative transportation planning. This includes, but is not limited to, the tasks of maintaining a long-range transportation plan, known as the Metropolitan Transportation Plan or Regional Transportation Plan, and maintaining short-range Transportation Improvement Programs. Through these short-range and long-range plans, RTPOs are responsible for transportation planning to improve a region's air quality, increase mobility for the region's residents, and improve transportation safety within a region.

Legislative History

The foundations of regional transportation planning organizations were under construction long before legislation required them. For example, in 1925 Cincinnati endorsed the nation's first

comprehensive plan that integrated concepts of transportation, utilities, parks, and land use.

In 1933 the Tennessee Valley Authority, the first multi-jurisdiction, multifunction agency that integrated economic, social, and physical planning, was formed and became the precursor to metropolitan planning organizations.

Concurrently, the Federal Highway Act of 1934 was the first to allow states to use up to 1.5 percent of federal highway funding to support surveys, planning, engineering, and other administrative work. However, at this time states were still the primary planning agencies, and it took nearly three more decades to establish dedicated funding for planning efforts.

Following the multi-jurisdiction lead of the Tennessee Valley Authority, in 1954 the council of governments movement began in Detroit and spread nationwide. In recognition that many issues were of interjurisdictional significance and difficult or impossible for each local government to solve on its own, these councils provided a forum for elected officials from multiple jurisdictions to act on behalf of their local government to address regional issues.

Planning grew in importance at the same time the council of governments movement gained momentum. The Federal-Aid Highway Act of 1962 was the first to require that states use 1.5 percent of any highway project's federal construction funds for planning. The act further fostered the importance of planning by requiring the use of the "3-C" transportation planning process: comprehensive, coordinated, and continuing.

Building upon the council of governments movement that began in the 1950s, the Federal Highway Act of 1973 created metropolitan planning organizations (MPOs) to carry out the role of regional transportation planning. These organizations were designed to serve as a conduit for allocating federal transportation funds. For a further description of the organizational structure and responsibilities of MPOs, please see the entry on Metropolitan Planning Organizations.

The act also expanded concern for environmental and social issues in transportation planning and required that local planners produce short-range transportation plans known as Transportation Improvement Programs (TIPs). The TIP is a short-term document, usually covering five years, that

implements the long-range regional transportation plan (RTP) through the construction of infrastructure and implementation of transportation management systems. Subsequent legislation has required regional transportation organizations to expand public participation in their planning process and to address environmental and energy issues.

In many states, regional planning organizations' responsibilities extend beyond the federally funded transportation infrastructure planning role mandated for MPOs. For example, regional planning organizations in California are responsible for transportation-related greenhouse gas reduction planning as well as for allocating some nonfederal transportation funds. In other states, regional planning organizations play a role in urban growth management and land use planning.

Structure

Today nearly 400 RTPOs exist nationwide. Each urbanized area in the United States having a population of more than 50,000 individuals belongs to one of these transportation planning organizations. As outlined in Title 23 Sec. 134 of the United States Code, transportation planning organizations must encompass the existing urbanized area and contiguous areas expected to urbanize within 20 years, and may encompass the entire Metropolitan Statistical Area, as defined by the U.S. Census Bureau. According to the General Accounting Office, half of RTPOs represent populations of less than 200,000 while some planning organizations represent millions of people.

In limited circumstances, of large geographic area and transportation system complexity, a metropolitan area may have more than one planning organization. Similarly, metropolitan areas may cross state boundaries, requiring multi-state planning organizations. These cases, however, are relatively rare. Of the 400 RTPOs, approximately 40 existing planning organizations cross state lines.

Title 23 U.S.C. Sec. 134 also states that metropolitan planning organizations "shall consist of— (A) local elected officials; (B) officials of public agencies that administer or operate major modes of transportation in the metropolitan area; and (C) appropriate State officials." In practice, regional transportation planning organizations may be comprised of directly elected officials or appointees from participating governing bodies, including

cities, counties, and tribal governments, as well as other government agencies such as transit service providers or public utility providers.

The policy makers are generally supported by technical advisory committees. The advisory committees may include technical experts, staff from local government agencies, and members of the public. In addition to advisory committees, RTPOs are supported by administrative and technical staff, though the size of the staff varies greatly from region to region. According to a report from the General Accounting Office, some RTPOs are supported by only a handful of staff while others have 100 or more.

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See Also: Air Pollution/Air Quality; Federal Transportation Policy; Metropolitan Planning Organizations; Regional Transportation Planning; Regional Transportation Plans; 3-C Planning Process; Transportation Improvement Programs.

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Regional Transportation Plans

Sometimes referred to as metropolitan transportation plans, Regional Transportation Plans (RTPs) are planning documents that outline the transportation needs of and planned transportation improvements for a multi-jurisdiction region that may comprise cities and towns, counties, and sometimes more than one state. These plans are intended to improve a region's air quality, provide for increased mobility of the region's residents, and improve transportation safety within a region.

Legislative History

Regional transportation planning is required by federal law, which has evolved greatly over the past century. While the Federal Highway Act of 1934 was the first to allow states to use up to 1.5 percent of federal highway funding to support surveys, planning, engineering, and other administrative work, there was no mandate to fund planning efforts until 1962. The Federal-Aid Highway Act of 1962 was the first to require that states use 1.5 percent of any highway project's federal construction funds for planning. The act further fostered the importance of planning by requiring the use of the "3-C" transportation planning process: comprehensive, coordinated, and continuing.

A decade later, the Federal Highway Act of 1973 expanded concern for environmental and social issues in transportation planning, required that local planners produce short-range transportation plans known as Transportation Improvement Programs (TIPs), and created metropolitan planning organizations (MPOs) to carry out the role of regional transportation planning.

In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) included a new requirement that planning organizations engage in "proactive and inclusive" public outreach. This new element of transportation planning law was intended to encourage public participation in the regional transportation planning process. ISTEA also required that local planning organizations consider 15 specific factors to ensure that the transportation planning process addressed issues such as land use planning, energy conservation, and environmental management. Importantly, it mandated that the

RTP must conform to the emissions reduction goals in the State Improvement Plan (SIP) required by the 1990 Clean Air Act. The plans need to contribute to reducing the number and severity of violations of the National Ambient Air Quality Standards (NAAQS) and to ultimately achieve those standards or the RTPs cannot be approved.

In 1998, the Transportation Equity Act for the 21st Century (TEA-21) streamlined the metropolitan transportation planning process and further expanded the role of public involvement in the planning process. TEA-21 also placed additional focus on environmental considerations.

The largest surface transportation investment in U.S. history, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, was signed into law in 2005. SAFETEA-LU expanded funding for environmental programs started within TEA-21, and the act implemented a new environmental review process for highways, transit, and multimodal projects.

In 2012, SAFETEA-LU was replaced by Moving Ahead for Progress in the 21st Century Act (MAP-21). While funding formulas had been changed, transportation planning requirements remained essentially unchanged from the 2005 legislation. Practitioners should note that many states impose local transportation planning requirements in addition to federal planning requirements.

Process

In any planning process, the first step is to identify the problems to be solved and issues to be resolved. In transportation planning, this is likely to include estimating future demand for transportation facilities and services. Planners, stakeholders, residents, and elected officials then identify goals and objectives for the region's transportation system.

Planners develop a series of transportation alternatives to meet those goals and objectives, either by changing the supply of or modifying the demand for transportation. Analysts then evaluate the proposed alternatives using complex computer models of transportation behavior, including air quality analyses of projected levels of pollutant emissions.

Analysts present the various transportation alternatives to the public and elected officials, who provide feedback and select a preferred alternative. Once a preferred alternative is selected, transportation agencies begin implementing the plan by

constructing new infrastructure, rehabilitating existing infrastructure, implementing transportation system management programs (e.g., signal timing and congestion pricing), and implementing transportation demand management programs (e.g., flexible work scheduling and carpool programs).

Analysts then collect data to monitor the transportation system. Data collection is an important step in the transportation planning process, allowing analysts and planners to evaluate the success of a transportation program and identify issues that require further attention. This transportation system information, in addition to demographic and economic forecast information, is then used to update projections of future transportation needs, and the process begins again.

Requirements

According to Title 23 Sec. 134 of the U.S. Code, a regional or metropolitan transportation plan must include the following elements:

- Identification of transportation facilities (including major roadways, transit, multimodal and intermodal facilities, and intermodal connectors) with an emphasis on facilities that serve national and regional transportation functions
- Environmental mitigation activities developed in consultation with federal, state, and tribal wildlife, land management, and regulatory agencies
- A financial plan that outlines both estimated project cost and anticipated sources of funding
- Operational and management strategies to improve the performance of existing transportation facilities in order to relieve vehicular congestion and maximize the safety and mobility of people and goods
- Capital investment and other strategies to preserve the existing and projected future metropolitan transportation infrastructure, proposed transportation, and transit enhancement activities

These plans must be updated at least every four years for regions designated as a nonattainment area, as defined in section 107(d) of the Clean Air Act (42 U.S.C. 7407 (d)), or any area that is subject

to a maintenance plan under section 175A of that Act (42 U.S.C. 7505a). All other regions may update their plan every five years.

Long-Range and Short-Range Plans

In addition to long-range (20 years or longer horizon) transportation plans, regional transportation planning organizations must develop a Regional/Federal Transportation Improvement Program (RTIP or FTIP). The TIP is a short-term document, usually covering five years, that implements the RTP through the construction of infrastructure and implementation of transportation management systems. These short-range implementation plans are required by Title 23 U.S.C. Sec. 134 and Title 42 U.S.C. Sec. 7506.

Projects in the TIP must be shown to conform to air quality standards and must be consistent with projects outlined in the RTP. All projects in the RTIP come from the first five years of the RTP. Projects are included in a TIP if they involve federal or state transportation funds, are regionally significant, or increase existing infrastructure capacity.

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See Also: Clean Air Act and Amendments; Federal Transportation Policy; National Ambient Air Quality Standards; Public Participation in Transportation Planning; Regional Transportation Planning; Regional Transit Agencies; Regional Transportation Planning Organizations; 3-C Planning Process: Transportation Improvement Programs.

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Residential Location Models

Residential land use takes up almost two-thirds of all urban land, while home-based trips account for a significant percentage of all travel activities. Hence, one of the most vital long-term, land use related decisions in the context of public policy and urban planning is that of residential location.

An urban area is developed from the mutual coupling and synthetic interaction between natural and human factors, and dynamic urban landscapes reflect intersections of economic development and human activities. Large-scale projects, including new sites for shopping malls and transportation infrastructure, illustrate how the physical environment continues to be transformed through the nexus of political, economic, and technological access and control.

It is the conventional wisdom that residential patterns and travel patterns are closely woven. Residential houses are regularly located along the sides of streets or roads. As a result, the population distribution is closely related to the street network.

Urban processes have complex subsystem elements that operate in diverse ways in the same geographical space. Initiating residential land uses pushes the growth of new land uses in the space. The solution to wasteful commuting, then, is minimizing the total commute to and from a city. In the optimal city, most journey-to-work trips would be intrazonal (that is, residence and workplace are in the same zone) and generate very little wasteful commuting.

The residential location model is crucial to the transportation-system planning process because household locations determine demand for community facilities and services, and modeling that

behavior holds great potential for improving long-range travel demand forecasting. For illuminating the nature of location choice, it is useful to understand which attributes impact these choices: both short- and long-term residential mobility decisions are determined by a variety of dynamic and complex driving forces, such as household membership, family structures, job status changes, and other socioeconomic factors involving various behavioral processes and considerations. Labor-force participation, job choice, auto ownership, and wealth investment all influence individual activity and travel patterns, while individual residences serve as a spatial anchor, impacting the spatial and temporal attributes of those movements.

Residential mobility decisions generate a new round of land use growth in a given neighborhood, which is usually symmetrically arrayed around one point of origin, but sometimes with directional distortion. The probability of an initiating residential use spawning another use in this field is a function of the distance away from the central cell, and which cells get developed will depend on how strong the competition is between different land uses being spawned by the particular land use in question.

A residential land use has the potential to spawn any number of different uses, but only one of these will occur in each time period. The spawning process is subject to a series of constraints, some within a narrow traditional neighborhood around the residence in question, which relates to density and type of uses in the neighboring cells, and it is also subject to regional constraints, which limit what each cell might be used for.

Urban residential models should balance the focus on socioeconomic activity and physical change at the level of residential land use and development. These residential models require spatial and sectoral interactions to be handled. Thus, the use of more explicitly dynamic models in urban policy making has great potential.

Researchers have suggested that planners consider various “aspatial” (not related to spatial data) variables, including demographic measurements, such as age, sex, and ethnicity; socioeconomic status, such as poverty, female-headed households, homeownership, and income; environment issues, such as housing density and amenities; linguistic barriers and households linguistically isolated; and



A dense housing development in Ontario, Canada, in 2005. The residential location model is crucial to the transportation-system planning process because household locations determine demand for community facilities and services.

transportation mobility issues, such as households without vehicles. In all cases, a fundamental question is, “What objectives are these households pursuing?” Fulfilling the expectations of households is a major component of public policy related to housing markets, job location, and transportation.

Location choice can also be rigorously constrained by residents’ strong preferences. In general, residential location choice and home type choice should be modeled jointly. This strong linkage between location and home type choice is very helpful to simulate household behavior and move residential markets toward meaningful housing policies. This linkage not only guides the association between the household and the rest of the human settlement, but it also determines, to some extent, the household’s budget for activity participation. With the passage of the Intermodal Surface

Transportation Efficiency and the Transportation Equity Act for the 21st Century, the integrated residential location and transportation model has gained renewed importance.

The Evolution of Research Models

There is a large body of research and analysis on housing choice. Modern research on housing choice was pioneered in the 1960s by William Alonso, who made assumptions based on a model of a “mono-centric” city with a rational complexity that also captured the most important essence of real-world issues: employment opportunities are located in a single center. In Alonso’s study, the residential choice of households is built upon the assumption that a utility function should be maximized by relying on the expenditure in goods, size of the land lots, and distance from the city center.

In the 1970s, other researchers further developed the work of Alonso by relaxing the ideal of a monocentric city filled with employment opportunities, but a weakness of all of these early works is that location is ultimately represented as one variable, that is, distance from the central business district (CBD). These models are, therefore, unable to deal with dispersed employment centers and asymmetric development patterns characteristic of the 21st century.

Geographers and transportation planners have also suggested a “gravity model” to predict the generation and extent of trips. In the early 1960s, Ira Lowry utilized the gravity model for residential location modeling, known as the Lowry model, wherein he hypothesized that retail trade and services are located according to the residential demand and that residences are distributed in relation to combined retail and basic employment. Workers are assumed to start their trips to home from work and distribute themselves across possible residential locations in relation to a gravity model. This important feature of the Lowry model dominates residential location models in many empirical applications.

Another school of research on residential location modeling is built on discrete choice theory. In the context of residential location, the consumption decision is a discrete choice between alternative houses or neighborhoods. Daniel McFadden in 1978 represented the earliest attempt to apply discrete choice modeling to housing location. Many

follow-up studies differed significantly in their model structures, the choice dimensions, and the explanatory variables considered in the analysis.

A variety of hypothetical urban simulations demonstrate the diversity of model types that can be handled within the framework as a prelude to more policy-relevant research and applications. In urban residential modeling, there are many intricate and dynamic models based on elaborate decision processes, where simulation must be based on customized software if their space-time properties are to be explored effectively.

However, these models have been criticized for being remote from policy, and lacking a focus on real-world planning applications and reflecting the serious disconnect between socioeconomic models—which form part of the urban economics, regional science, and transportation traditions—and this simulation-based, spatially explicit modeling. In other words, urban simulations have been marked by a lack of application to real policy contexts, notwithstanding their obvious relevance to topical problems such as urban sprawl.

Changes of the quantity and scope of residential land use and location choice decision have a profound impact on urban residential development and function, as well as on the role of the city within the region. Amid the variety of development challenges and opportunities spanning the urban landscape, life cycles apply both to the physical stock and the activities that occupy the space over time.

Residential land uses are structured through their life cycles. Urban simulations can be developed to great effect using powerful methods of visualization built around geographic information systems (GIS). Given the intensified globalization and competition in the context of time and space, understanding and harnessing the residential location complexity requires various mathematical modeling and planning in relation to all facets of cities and regions.

In recent decades, a number of modeling strategies have been developed and adopted to better understand and predict residential land use, such as cellular automata and agent-based modeling. At the same time, various urban modeling methods are being constructed based on an understanding from empirical studies.

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See Also: Activity-Based Models; Employment Location; Gravity Models; Integrated Transportation and Urban Land Use Planning Models; Network Modeling; Transportation Impacts on Land Use; Travel Modeling.

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commuters used trains, buses, and automobiles in order to make their commutes. However, more recently, some have begun to commute from their home in the city to a day job in the suburbs and then to return at night to the city. This phenomenon has been termed "reverse commuting" as the commuting direction is the reverse of what has been the normal commuting direction, which is from the suburbs to the city.

There are benefits to reverse commuting. One benefit is that the reverse commuter travels in the opposite direction to the main body of traffic. This is usually less stressful because most of the traffic is moving in the opposite direction, which opens the road for the reverse commuter. It also benefits the transportation company in the case of buses or trains because their passenger load is increased.

Generally, the reasons for commuting even long distances have been lower housing costs and better schools in the suburbs offsetting the cost of travel to jobs in central cities. However, for reverse commuters a good job in the suburbs may or may not be matched in the inner city, where housing costs may be higher and the schools often of lesser quality. On the other hand, the cities are centers of culture and entertainment so young people may find reverse commuting to be rewarding. In contrast, the family interests of those commuters with children may direct them toward suburban living and urban employment.

New York City

The New York City area is a strong example of the traditional commuter pattern. Rail transport has been developed to carry commuters from all directions—Long Island, Westchester County, New Jersey, and southern Connecticut—into New York City on lines such as the Long Island Rail Road, Metro North, and New Jersey Transit. This promoted the suburban development of 120-mile-long Long Island. In recent years, reverse commuting has become very important to the continued development of Long Island as a business center in its own right.

Although reverse commuting is somewhat less prevalent in New Jersey and Connecticut, which have their own central business districts—such as Newark, New Jersey, and Stamford, Connecticut—Metro North and New Jersey Transit lines provide both commuter and reverse commuter transportation.

Reverse Commuting

Commuting is taking transportation for some distance to go to work, attend school, or for some other regular activity. After World War II, a great many people moved from the city to the suburbs. From there, many middle- and upper-income workers then commuted into the city from their homes in the suburbs. They then returned at night from their city jobs to their suburban homes. The

Reverse commuting from New York City is growing. As of 2010 it was at 300,000 people per day and growing. The reverse commuters left the city for Long Island, New Jersey, and other locations.

Southern and Western Patterns

Commuting and reverse commuting followed different patterns in the Sun Belt of the south and southwest. Unlike the older northern Frost Belt (or Rust Belt) where the older, more traditional cities were much more centrally developed, newer Sun Belt cities, such as Washington, D.C., have spread out significantly as businesses sought less expensive office space. The D.C. metropolitan area urban sprawl into Maryland and Virginia was caused by several factors. One was the limit on the height of buildings in Washington.

A second factor was the existence and extent of its robust transit system, which allowed people to take the Metrobus or Metrorail or to carpool via high-occupancy vehicle (HOV) lanes rather than engage in individual driving. The result has been a more decentralized or polycentric development pattern. Other urban areas have had similar experiences, and many if not most commutes (even in older cities) are now suburb-to-suburb rather than suburb-to-central city. For example, in Los Angeles the vehicle traffic can be much heavier in the morning on the Santa Monica Freeway leaving downtown Los Angeles than coming into Los Angeles.

Legislators Promote Reverse Commuting

A stimulus for reverse commuting was the 1996 Welfare-to-Work legislation adopted by Congress. An issue that was debated in the legislative process was the role of public transportation in getting people to work. Since the inner areas of older cities have decayed and, in many cases, have been resistant to urban development, a grassroots movement to promote reverse commuting for jobs emerged. The Job Access and Reverse Commute (JARC) Program was enacted to provide funding for transportation services to aid welfare recipients and other low-income individuals in part by aiding reverse commuting. The 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) provided Federal Transit Administration funds for JARC programs.

Recent research on reverse commuting has found that lacking a means of transportation is a major form of social exclusion in the United States. The presence of an urban unskilled “army” or workers without access to bus or rail transportation is a major impediment to their employment and economic development.

In sociogeographical terms, this is a “spatial mismatch” that can be remedied with access to transportation. It is a policy concern that first emerged following the urban riots of the late 1960s when studies identified a lack of job opportunities as a significant factor leading to the civil unrest.

Studies of reverse commuting have been focused on a number of cities, suburban, and other localities. Studies of reverse commuting have been made of Staten Island (New York City Department of Planning), Chicago, California, Philadelphia, Kansas City, and other locations such as Onondaga County, New York. Research has pointed to the development of communications technologies that allow suburban back-offices to communicate easily with urban-core offices, further encouraging business decentralization.

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See Also: Commuter Paradox; Commuting; Job Access and Reverse Commuting Program; Jobs–Housing Balance/Spatial Mismatch; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Traffic Demand Management; Transit Lines/Networks; Transit Ridership.

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Risk Analysis/ Assessment

Preventing and recovering from events that halt or delay people and products in transit is important to economic growth and security. Grounded in safety and systems engineering, risk analysis became closely identified with assessing and reducing risks associated with nuclear power reactors after the 1979 accident at Three Mile Island in Pennsylvania. It also has been applied to hazardous waste management, control of biological and chemical agents, food security, medical decision making, and natural hazards.

The context for this introduction to risk analysis was an analysis developed for a 60-mile segment of Amtrak's Northeast Corridor passenger rail line between Trenton, New Jersey, and Penn Station in New York City, a stretch of rail that is shared with the New Jersey Transit commuter line.

Risk Assessment

In the context of transportation, risk assessment answers the following three questions:

1. What disruptions can occur?
2. What are the chances that serious events can occur?
3. What are the health, ecological, and economic consequences if the events occur?

Analysts create scenarios, such as a major bridge failure, a leaking tank car, or a terrorist attack on a train or a rail station. They use event or fault trees to build out risk assessment scenarios. Event trees begin with the event and follow it through each stage, whereas fault tree analyses start with an end state and work backward to identify the event or sequence of events that triggers the most serious consequences.

In the case of short-term signal and power failures, and other short-term problems, the likelihood of an event can be estimated from historical records or expert experience. When there is no historical record, such as a major bridge failure or a terrorist attack, the event is assumed as a given.

Death is at the top of the consequences list, followed by injuries, psychological distress, ecological destruction, and economic impacts. For example,

a research team simulated the consequences of a bridge failure of one-year duration and an industrial accident that sent a lethal plume of chlorine into the environment.

Researchers can measure the immediate and local impacts of a bridge failure by estimating how many people and how much cargo was halted and for how long, and how much physical damage there is to the rail system, as well as any injuries and fatalities. What they cannot as easily estimate is how many people will lose confidence in the rail operations, and consequently drive to work, and how many business owners will shift their operations if too many serious events occur with long-term regional consequences. It is also difficult to readily assess the length of the impact.

For example, the terrorist attacks in the United States on September 11, 2001, that used commercial aircraft, and the London subway bombings in 2005 dampened public use of these modes for many months. Risk assessors, in short, estimate the likelihood of specific events and assess their consequences as the impacts ripple across the landscape and through time.

Risk Management

The focus of risk managers is to determine what to do to eliminate or reduce the consequences of a damaging event. Managers answer three questions:

1. How can consequences be entirely or partly prevented?
2. How can recovery be enhanced if the scenario occurs?
3. How can key local officials, expert staff, and the public organize to reduce the consequences?

Risk managers control human, financial, legal, and educational resources. In the case of the rail system example, managers can improve maintenance; add monitoring equipment at stations, on tracks, and trains; improve energy networks in order to reduce the chances of power losses; add more security officers; and improve the capacity of their workforce to respond.

Yet, the best efforts to prevent risk events sometimes fail. Risk managers need resilience plans to restore the system as soon as possible. If the passenger trains stop running or freight is blocked by

a bridge failure, management needs a method of bypassing the blockage and offering alternative mode choices, and it needs to develop a process to rebuild the system, as well as the public's confidence in it.

The most consistent problem in risk management is misunderstanding about who plays which roles in preparing for, responding to, and recovering from an event. Transit workers and upper-level managers should know how to communicate with passengers, how to prevent panic, and how to deal with suspicious people and objects. For example, one research group developed a 15-minute video for the U.S. Department of Homeland Security intended for rail workers who walk the tracks looking for potential dangers and for suspicious people, a 25-minute video about chemical weapons for subway personnel, and are currently preparing one for bus drivers.

Risk analysis is a multidisciplinary field, and books written by scholars with different backgrounds provide numerous perspectives. Risk analysis as a discipline is moving very rapidly, and so those interested in the topic can also consult *Risk Analysis: An International Journal*, especially "Ten Most Important Accomplishments in Risk Analysis," a 2012 article that summarizes what are believed to be major accomplishments during the last 30 years.

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See Also: Airplane Disasters; Automobile Accidents and Prevention; Harbor and Port Security; Hazardous Materials Transport; Pipeline and Hazardous Materials Safety Administration; Port Inspections; Terrorism, Transportation Systems as Targets of; Transit Safety; Tunnels, Safety and Security Issues in.

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Road Diets

"Road diet" is a common term referring to roadway reconfiguration. The most common example involves converting an undivided four-lane road into three lanes made up of two through lanes and a center two-way left-turn lane. The remaining road space can be reallocated for other uses, such as transit vehicle lanes, bike lanes, pedestrian walkways, or parking. The resulting improvements generate benefits to users of all transportation modes and can include reduced vehicle speeds, improved mobility and access, reduced collisions and injuries, and improved quality of life in the community being served.

Studies have shown that road diets undertaken in various cities have had multiple benefits, including decreasing vehicle travel lanes for pedestrians to cross, reducing the likelihood of accidents; providing room for a pedestrian crossing island, improving safety for bicyclists when bike lanes are added; providing the opportunity for on-street parking; improving vehicle (including bicycle) and pedestrian mobility and access; reducing rear-end and side-swipe crashes; and improving speed-limit compliance, which decreases crash severity when crashes do occur. In transportation planning and engineering, road diets have also been used

successfully in “weaning” traffic off some roadways, also known as reversing induced traffic.

Why Put a Road on a Diet?

During the past several decades, there have been many roadways constructed in urban areas that have four lanes. When a road is widened, it often comes with a trade-off: more and wider lanes, with less sidewalks and paved shoulders. In many cases, these roadway improvements allow more cars into traffic streams, encouraging communities to become more car dependent. These changes often generate higher vehicle speeds, noise, and danger to people trying to walk, bike, shop, or live on or near main streets.

Use of public transportation is sometimes discouraged when pedestrians have difficulty crossing four lanes of traffic to get to a transit stop. Minimal areas of sidewalk and vegetation also detract from a community’s visual appeal and can impact the health of neighborhoods and businesses on many levels.

When drivers use four-lane roadways, they assume that there are always spare lanes in their direction. They tend to drive faster than they should. Motorists using multilane roads seek to match speeds of other drivers, and speeding drivers tend to set prevailing speeds. As traffic volumes increase, especially at rush hour, risk of high-speed driving increases.

During peak volumes of traffic, right- or left-turning movements occur. When a car stops in a moving traffic lane to turn left, it causes congestion, blind spots, unsafe lane changes, and changes in vehicle speeds. Quick lane-changing maneuvers can lead to serious rear-end crashes. Drivers may also move from lanes of slowing traffic directly into the backs of other vehicles that have slowed for their turns. These are only a few examples of traffic and driving behaviors on four-lane roads that have been known to cause accidents.

Benefits

When roadways have been modified from four travel lanes to two travel lanes with a two-way left-turn lane, research has shown a 29 percent reduction in all roadway crashes. Road diets provide a center turn lane so that left turns are simpler. A driver crosses only one lane of traffic at a time, resulting in fewer blind spots. With an undivided four-lane road, a driver must find a gap in two or



Two lanes of a highway overpass undergo demolition in Marseille, France, in 2011. Among those roads that may make good candidates for reconfiguration are those with 8,000 to 15,000 average daily traffic (ADT) and those with safety issues.

three lanes of traffic at once to make a left turn. With only three lanes of traffic, there are also fewer intersection conflicts.

The benefits to pedestrians include reduced crossing distance and fewer midblock crossing locations, which account for more than 70 percent of pedestrian fatalities. There are fewer blind spots because there is only one lane in each direction, thus there is less obstruction by traffic. Also, top vehicle speeds in a three-lane system are generally lower. Finally, some road diets reallocate “leftover” road space for pedestrian crossing islands.

A roadway that is reconfigured to create bike lanes is being met with much success and enthusiasm in many cities. The installation of bike lanes significantly increases safety for cyclists and encourages more people to commute by bicycle.

Without bike lanes, a cyclist is always at risk of being involved in a motor vehicle collision, of being “doored” by someone getting out of a parked car, or being “mirrored” by motor vehicles passing the bicycle so closely that their mirror hits the cyclist. Many people are embracing the rise of bicycle commuting because it can enhance the health and well-being of their communities.

Installation of bike lanes, sidewalks, and vegetated areas adds to the general appeal of a roadway and adjacent neighborhoods. If sufficient space is available, cities can add trees along the sidewalks for aesthetics. Trees along streets change the feel and character of a roadway. After a road diet and the addition of landscaping, the message given by a street is that “this is a nice community; please slow down and enjoy.”

Road diets can lead to improvements in use of space, making walking and bicycling more pleasant. Other benefits include the economic impacts on businesses of a street that caters to all users, as well as increases in real estate values and enticement of additional smart growth.

Potential Road Diet Candidates

When considering a road diet for a particular site, city planners may use some guidelines established through research and case studies of road diets already implemented. Location criteria may include the following: moderate traffic volumes (8,000 to 15,000 average daily traffic, or ADT), roads with a history of safety issues, main streets, commercial reinvestment areas, economic enterprise zones, entertainment districts, historic streets and scenic roads, transit corridors, and popular bicycle or pedestrian routes.

Road diets can be low cost if planned in conjunction with reconstruction or simple overlay projects, because a road diet mostly consists of re-striping. Roadways with moderate traffic may be good candidates for a road diet and should be evaluated for feasibility. It has been shown that roads with 15,000 ADT or less have had very good results in the areas of safety, operations, and livability. Driveway density, transit routes, and the number and design of intersections along the corridor, as well as operational characteristics, are some considerations to be evaluated before deciding to implement a road diet.

An evaluation should be conducted to analyze and understand the effects of the proposed

changes, obtain input from community members, and ensure the appropriate elements are included in the project. Of the various configurations for a road diet, it must be decided which one, with which components, will best suit the needs of the local motorists, pedestrians, and cyclists, as well as those of homeowners, retailers, and other business establishments.

Improvements to intersection turn lanes, signing, pavement markings, traffic control devices, transit stops, pedestrian and bicycle facilities, and landscaping all may need to be planned to support this concept.

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See Also: Bicycles; Bikeways/Bike Lanes, Road Design Issues of; Complete Streets; Highway Removal; Intersections; Livable Streets; Sidewalks; Smart Growth; Visual Pollution.

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Road Ecology

Road networks enmesh North America in a rapidly expanding and intricate web that is designed to meet the demand for fast, efficient transportation. While roads consume and directly alter

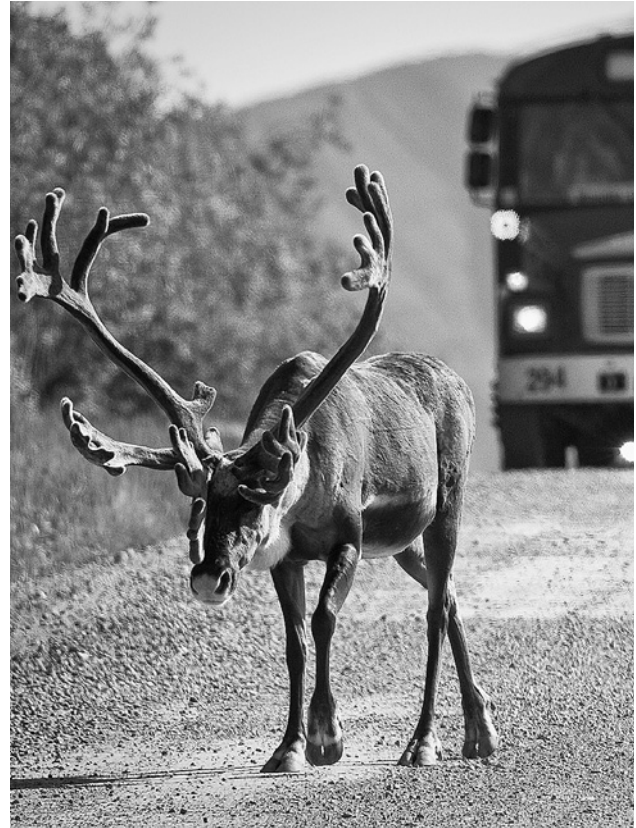
landscapes, they also indirectly affect areas and wildlife surrounding road infrastructure; for some wildlife populations, these road effects may be experienced hundreds of miles from the road itself. Importantly, the ecological consequences of roads not only are observed for each individual road but also are cumulative, as each road in the network becomes closer and closer to the next.

It follows, then, that the highway infrastructure in North America has been suggested for decades to be the single greatest threat to many wildlife populations and to biodiversity conservation. Primarily, this is because vehicular traffic on highways causes millions of wildlife deaths every year. However, in tandem, roads also directly interrupt ecological processes (such as stream flow or runoff), may contaminate air and water, and increase light and sound pollution.

Roads also challenge animal survival through habitat fragmentation (the loss and breakup of suitable habitat), road avoidance, the imposition of barriers to movement, and alteration of ecological processes (for example, changes in predation rates). Any one of the latter can increase the risk of species extinction or extirpation. The discipline of road ecology, which was developed to understand and attempt to mitigate these risks, describes the diverse science that merges biology, ecology, geography, and transportation and urban planning.

Road ecology and the specific effects of roads on wildlife have been studied since the 1970s and a number of key literature reviews have summarized research on road-related ecological disturbance effects. The *Proceedings of the International Conferences on Wildlife Ecology and Transportation* (ICOWET), offers alternative sources that describe road ecology. Recent research trends (that is, in the last 15 years) have focused on wildlife mortality, pollution/contamination effects of roads and vehicles, and mitigation approaches. In turn, these investigations have focused on mammals, birds, amphibians, and fish.

Although small mammals have been the focus of most fragmentation experiments, large mammals have received the greatest attention in road mortality and mitigation studies. Other authors have accurately noted that insects also are killed in vast numbers. Yet, despite their potential keystone role in ecosystem services, the effects of such mass insect kills remain poorly documented.



A bus approaches a caribou in the road in Denali National Park in Alaska. In Canada's Rocky Mountains, ungulates do not have their movements impaired until traffic reaches high volumes, around 15,000 vehicles per day, but carnivores may be impacted even at low traffic volumes of 500 to 5,000 vehicles per day.

Ecological Effects

Road effects on wildlife are classified as direct or indirect. Direct effects are those that immediately impact the animal, for example, when the animal is killed by a vehicle. Indirect effects are those that influence the animal negatively in a secondary way, for example, the animal avoids crossing a road due to fear, or animals leave an area due to increased human presence. With specific reference to terrestrial wildlife, the key disturbance effects include habitat loss and degradation of quality (for example, through pollution or alteration of processes), reduced movement and loss of access to vital resources, road avoidance and mortality, increased human exploitation, and disruption of ecological processes that maintain wildlife populations. Some ecological effects are so pronounced they are identified as "phenomenon" that may include both

direct and indirect effects; these include the “barrier effect” and the “road effect zone.”

The first of these, the barrier effect, results when animals cannot move across the landscape due to the effects of traffic on the highway. These effects may apply to terrestrial or aquatic animal species. Here, terrestrial animals are either directly killed by vehicular traffic as they attempt to cross between isolated habitats, or they may avoid crossing roads for fear of detection. Aquatic species are affected by changes in stream turbidity, alteration of stream flow, narrowing of stream channels, pollution, and loss of necessary habitat for dispersal.

In ecology this phenomena is termed “the barrier effect.” The second ecological effect is the road effect zone, which includes areas adjacent to roads into which adverse effects propagate. Depending on the specific effect, the consequences may be experienced hundreds of meters/yards into the surrounding habitat and can vary over time (of day or season), and can vary for each terrestrial or aquatic species affected. The development of a road through a previously contiguous habitat can result in increased “edge effects,” which include but are not limited to increases in light and sound penetration into forest core areas, alteration of species that exist along the edge, crowding of species into habitat patches that are farther from roads, changes in aridity of the forest due to greater wind penetration, tree damage and windfall, and alteration of soil and water quality.

Indirect effects also include changes to animal movement patterns and behavior in areas adjacent to roads. Road avoidance has been documented in mammals and reptiles, but some animals such as coyotes have learned to cross roads when traffic volume is low. Such adaptive behavior is no guarantee of survival, however, as wildlife have not evolved in a context that would allow them to comprehend the speed of vehicles. Other researchers have found that road traffic causes adaptive shifts in home ranges for species such as black bears, grizzly bears, cougars, bobcats, coyotes, and wolves.

The permeability of a road (that is, how easily it can be crossed) is directly related to traffic volume. Different tolerances and crossing abilities have been observed for various species. In particular, in the Rocky Mountains of Canada, carnivores experience a significant reduction in movement rates at moderate to low traffic volumes (500 to 5,000 vehicles per day) compared to ungulates, whose movement

rates were not impaired until high traffic volumes (15,000 vehicles per day). This has conservation implications, as lower permeability results in fewer individuals of a population moving across a road, which in turn can decrease genetic exchange and reduce genetic diversity and adaptability.

Behavioral and morphological conditions may also affect species survival in road-fragmented habitats: small and slow-moving species, herd or social animals, and those species or sexes of species that must cross roads more often may be at increased risk of mortality. As an example, researchers have found that amphibians can be difficult to see and during migratory periods may be struck in great numbers on roads.

Likewise, herding (for example, elk) and social animals (for example, wolves) can be hit in greater numbers on roads because of their affinity and need to stay together. Species that have a primary provider during certain times of year (for example, one animal is dependent upon the other during the denning period) have shown higher rates of mortality by sex and reproductive status.

Other animals, such as grizzly bears, have been observed to alter their movement patterns within home ranges to attempt to minimize such contact. Importantly, roads can also attract wildlife, providing sources of water, food (for example, grasses or small mammals), warmth (for example, sleeping on roads as they hold heat), or easy travel relative to movement through adjacent habitat (for example, when snow is deep, animals may use roads to move).

Roads alter the microclimate health in adjacent areas, which can disrupt natural processes that are critical to wildlife community structure and function. For example, water flow, fire occurrence, nutrient cycling, predation rates, and the increased presence of invasive species may all affect wildlife species abundance and distribution. Moreover, contamination may occur when road maintenance chemicals are applied or when vehicle discharges spread into adjacent air, land, and water. As an example, two-stroke engines (such as are found on snowmobiles) discharge particulate matter and heavy metals many hundreds of meters/yards into forests and fields adjacent to roads. Heavy metals have direct impact on plant and animal species adjacent to roads but may also move through the trophic chain, resulting in bioaccumulation of toxins in other species.

Likewise, salt and slip reduction products, used in winter to maintain travel and mitigate the effects of ice, can seep into surrounding habitats during periods of snow melt, or are pushed into adjacent rights-of-ways during road clearing. Soil erosion from road maintenance may also affect stream flow and vegetation adjacent to roads. Increased sediment loads and contaminants in water systems affect both aquatic and terrestrial species.

Lastly, roads play a role in the transport of invasive wildlife species and disease. The creation of road networks is now recognized to facilitate connectivity and transport of plants and animals from previously isolated patches into new habitats (for example, domestic squirrels, invasive insects). Such events can trigger trophic changes in species composition and dynamics, and the resulting cascade of effects is not understood.

Mitigation

“Highway mitigation science” describes the research and design of roadway and human-made structures that serve to reconnect habitat that has been fragmented by the road: the aim is to reduce mortality and reconnect individuals within a population or reduce mortality of wildlife on highways. The characteristics of roads (for example, width, traffic volume, speed, and type) and condition of the driver have been studied and found to influence vehicle-wildlife collision frequency and lethality. For instance, wildlife species reportedly are hit by vehicles less often if roads have high embankments and more often when heavy forestation is adjacent to roads. Notably, vehicular collisions frequently are related to the intersection of migration routes and roads.

Mitigation includes built structures and is implemented in places where wildlife mortality on roads becomes problematic to endangered species, or where human-related deaths and vehicle insurance costs become too large. Road mitigation includes such things as raised crossing structures, culvert underpasses, open spans of highway over creeks, exclusion fencing, and speed zones, which, in theory, are developed to facilitate movement of wildlife across roads and reduce wildlife mortality.

While this is a growth area of research, most early studies focused on the comparison of effectiveness of mitigation types, indicating that open spans of highway or overpasses of much greater width than 75 yards have efficacy for movement relative to

other mitigation structures. More recent studies have examined the effective placement of mitigation structures and have found that placement of structures tends to follow engineering requirements of building, or are single species in design, rather than addressing ecosystem or multispecies movement requirements.

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See Also: Airports, Environmental Issues and; Aviation Safety, Wildlife Strikes and; Harbors, Environmental Issues of; Wildlife Crossings and Barriers.

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Road Inventory

A road inventory is a compiled data resource that can provide various categories and layers of information based on the structural conditions and status of roads within a given area or jurisdiction. Road inventory is very useful, not only for planning purposes in the maintenance of safe surface transportation, but also for its utilization during funding requests. Any detailed request for thoroughfare improvement or widening, bridge repair, or highway construction that is submitted to the U.S. Department of Transportation (USDOT), or to similar bodies at the state level, generally requires a road inventory as one of its core documentation features.

Development

Road inventory reports have for decades been considered an essential part of the management, planning, and funding cycles of local, state, and federal transportation authorities and administrators. The hundreds of billions of dollars budgeted for and spent from the federal level on down for roadway design, construction, and maintenance, along with such integral or ancillary features as sightline improvements, bridges, culverts, tunnels, signage and traffic signals, electronic monitoring systems, ecological and civil remediation, and other matters have been a powerful incentive for the development of better road inventory capabilities.

This funding availability and its often strict compliance rules and guidelines have provided longstanding reasons for localities and states to progressively—and competitively—develop their ability to demonstrate road-improvement need, provide evidence of intelligent oversight, and show competence in project management.

Mileage Reports

Most state transportation authorities compile, produce, analyze, and file annual reports, including road mileage data within their jurisdictions. The essential data will often be footnoted or electronically layered with reference to such criteria as segment mileage and name, jurisdiction name, year of initial construction, roadway dimensions, material makeup of pavement, shoulder width and makeup, speed limits, general condition, status of maintenance activity or scheduled work, type and weight of conveyance restrictions, erosion or related risks, and special notes. Increasingly, the road inventory documentation may be linked to further documents that provide information on how certain road segments are part of proposed or budgeted projects within a five-year horizon.

Responsibility within a given jurisdiction may extend well beyond the immediately obvious. In South Dakota, for example, the transportation department (SDDOT) maintains an annually updated road inventory of all the nonstate public roads. The motivation behind this effort is revealing. The SDDOT states

The roadway information is necessary, to meet reporting needs, support in departmental decision making, development of state's certified

mileage report, and other mileage statistics utilized by state and federal authorities for the purpose of funding allocations and special studies.

Considerable effort and state resources are expended in what is in this case a collaborative effort between SDDOT, the Northeast Council of Governments, South Eastern Council of Governments, First District Association of Local Governments, Planning and Development District III, and officials and employees who staff a full range of other federal, state, county, township, and city agencies and panels that each exercise some measure of jurisdiction over public roads in South Dakota. Each of these entities, by virtue of the interconnectedness of the roadway system and its support structures, has some insight into and data-gathering ability for those public roads that the state itself does not control or maintain—but that often prove to be vital links in the planning and maintenance of safety, security, and adequate capacity over the entire road network.

Technological Advances

Geographic information systems (GIS) are increasingly important—if not essential—for maintaining compliance with new ways and means of managing road inventory. Their use has become a central component in meeting the expectations of the funding sources that are tasked with receiving, reviewing, and querying the funding requests from all 50 states and thousands of municipalities and other jurisdictions.

The earliest GIS software was developed in the late 1960s; its utilization within the forestry management sphere caught the attention and captured the imagination of many within such domains as urban planning, housing development, conservation advocacy, coastal protection, and transportation policy. Many features have been added and refined by specialists working in each of these fields.

Data typically originated from on-site handheld surveying supplemented by remote sensing technology, such as radar. Ultimately, GIS has been greatly enhanced by the advent of the Global Positioning System (GPS) and the development of compiling techniques and display software that supports this merger of ground-based and satellite-enabled data.

Some states use a linear referencing system (LRS) to more intuitively convey key road inventory

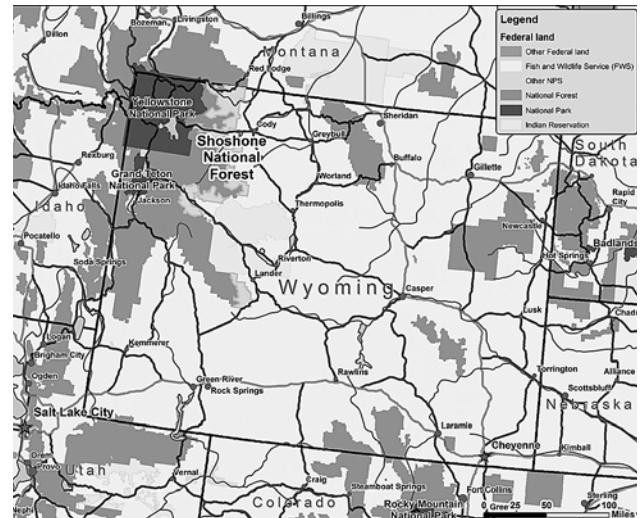
information that may not be clear from the basic x- and-y-coordinate type of data available through GPS and GIS. The North Carolina DOT, for example, has employed a new software system that matches up the fundamental GIS data with its separately derived linear data—such as distance measuring on the basis of landmark point to landmark point. The LRS can show very recognizable and important data, such as the category of planned or ongoing road inventory modifications: route changes, road additions, renamed roads, and road abandonments. LRS also facilitates the generation of both spatial and tabular reports.

Another tool is the geomorphic road analysis and inventory package (GRAIP), which integrates known scientific impacts of roads on water quality. GRAIP is used in conjunction with GPS- and GIS-sourced data. To the road and topographic data supplied by these sources, GRAIP then applies variable indices for surface erosion, sediment flow and accumulation, slope stability, and related hydrology-generated factors. Use of GRAIP has been refined by, among other specialists, a team based at the Rocky Mountain Research Station operated by the U.S. Forest Service.

The design and development of GRAIP stemmed in part from the work of fisheries biologists; the domain of these scientists' expertise converges with that of surveyors and construction engineers, where the physical features to be inventoried include culverts, stream crossings, and heavy roadway drainage areas. Proponents of using GRAIP contend that it can help reduce the costs of watershed management while supporting more intelligent decision making in watershed-restoration projects, each of which has prominent road-surface and right-of-way issues as part of its inherent structure.

Comprehensive Data

Paved roads are only one component of contemporary road-inventory databases. For example, in January 2013, the U.S. General Services Administration promulgated a request for a new contractor to upgrade the road inventory system for the federal land-management agencies, which include such bodies as the U.S. Fish and Wildlife Service, U.S. Forest Service, National Park Service, Bureau of Land Management, Indian Reservation Roads, and Army Corps of Engineers. Noted in the request was the fact that the necessary inventory system upgrade would encompass a broad array of features to include



A map of the Shoshone National Forest in Wyoming was created using U.S. government geographic information system data and ESRI's ArcGIS, a software tool used for road inventories.

“paved and unpaved roads, trails, parking lots, boardwalks, bridges, docks, airstrips, culverts, and signs.”

The solicitation was in compliance with the Moving Ahead for Progress in the 21st Century (MAP-21) program, under auspices of the Federal Lands Transportation Program. This specifically calls for collecting

condition and feature information on transportation assets and to make available the spatial and tabular data in such a way that it can be used in a geographic information system (GIS) to create and disseminate electronic reports.

Nongovernmental Actors

Some citizen-based organizations and privately held corporations use road inventory data in conjunction with other databases to help them utilize information in a holistic manner in accordance with their mission goals. For instance, the Pacific Stewardship, a regional forestry and natural resources consulting firm based in the Deschutes River Valley of Oregon, embraces a wide range of sophisticated mapping technologies. Among these are a forest projection system, landscape management system, and fire modeling and analysis software.

As part of its efforts, Pacific Stewardship has conducted a variety of combined forest and road inventory and vegetation and road inventory surveys.

These have been done on behalf of private landowners, local park management entities, regional stakeholders, natural resources conservation advocacy organizations, and both state and federal agencies. Typical services include vegetation delineation and typing, road and stream mapping and assessment, and customized inventory design, installation, and actual compilation of the data. Training, from the outset to the finalization of data compilation, is an essential part of the inventory service.

Pacific Stewardship notes that by installing a comprehensive road inventory, conservation and forestry clients can tap the data to intelligently “build maintenance and repair schedules, expand road networks for future harvests, and identify roads for decommissioning.”

Software tools in use by Pacific Stewardship come from several different technology and service provider companies. The company ESRI, for example, is tapped for its ArcGIS and ArcPad systems, which Pacific Stewardship uses for field-based mobile mapping, plot installation, and navigation. Also in use is ArcPad Studio to create customized data collection forms. Handheld mobile computers are used in the field; these are generally of the ruggedized Nomad line manufactured by Trimble, and are loaded with consumer- and survey-grade GPS data—using software. These platforms also operate Terrasync and Pathfinder Office software for purposes of custom data dictionary compilation and post-processing work.

Bikeway Inventory

In Massachusetts, state transportation authorities (MassDOT) have inherited and built upon very ambitious bikeway plans first promulgated by local towns, counties, and other substate bodies. In recent years, the state has found it necessary to compile and produce an increasingly accurate and comprehensive set of bikeway inventories, policy statements, and expansion and funding plans for this growing segment of its official responsibility.

In its 2011 year-end report, MassDOT expressly detailed the needs and priorities of this effort as it sought to catalog and categorize bikeways across Massachusetts in its Bicycle Facility Inventory (BFI), and to define the plans for each segment of what has become termed the Bay State Greenway. The MassDOT’s “Bicycle Facility Inventory Report 2011” states the following:

While a fundamental purpose of the BFI is to reflect existing accommodations for bicyclists, the BFI more broadly attempts to represent the whole spectrum of bicycle facility development . . . The spatial data in the BFI contains existing facilities across the Commonwealth, as well as projects in construction, design, or feasibility study phases, and those that are simply proposed or envisioned at this time. Both on-road accommodations (bike lanes and shared-use lanes on marked and unmarked routes) and off-road (shared-use paths) facilities are included. The BFI is intended to be useful not only as an inventory, but also as a planning tool, to show not only what bicycle facility network exists in 2011, but what may be developed in the future.

Getting to the heart of the matter, MassDOT specified that the BFI would be utilized in much the same manner as its annual road inventory (RI), that is, to clarify policy, prioritize planned activities, and empower the funding request function. MassDOT explained the relation—and integration—of the two document systems in the following terms:

Like the RI, the BFI requires continuous maintenance. It is intended to form the basis for development of other data by a broad range of users, who require continuity across update and release cycles and who need dependable keys to attach their own data. A portion of the BFI consists of data maintained in the RI itself, and as public data, is subject to review and requests for corrections by other public agencies, as well as the public at large. Because on-road accommodations are tied dynamically to the RI, improvements in that data layer are automatically inherited by the BFI.

To build and expand the usefulness of the bikeway inventory, MassDOT tapped a wide range of inputs, applying data sourced from regional planning entities, municipalities, advocacy groups, and project engineers. In order to maintain consistent identification of key bikeway features, the BFI uses a unique identifier for every feature that is carried forward in subsequent research and funding cycles.

The data in the BFI is layered and linked in order to include the latest updates on the greenway plan, local project status, physical characteristics,

involved agencies and entities, usage statistics, and external references. Design review was in process for more than 70 road-segment improvement projects at year-end 2011, MassDOT noted, to include new bicycle lanes, usable shoulders, shared-use markings, and multiuse trails.

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See Also: Bicycle Commuting; Highway Construction and Maintenance; ICT, Social Impacts of; Planning, Programming, and Budgeting Systems; Transportation Planning.

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Road Pricing Schemes, U.S. and International

Road pricing involves charging road users directly for their use of road space in accordance with their level of usage. Systems may be divided into urban and interurban initiatives. Urban road pricing refers to schemes within defined parts of specific urban areas and/or during a particular time period, and there are a limited number of examples across the world.

Interurban pricing involves charging road users for their use of interurban roads, typically highways of a strategic or trunk nature. Interurban road pricing includes the traditional tolling of privately owned and operated roads, where tolls are principally associated with highway financing, as well as user charges for the publicly owned parts of the interurban road network imposed by government.

There are three principal motivations for road pricing:

- To raise revenue (for example, for the construction and maintenance of roads themselves)
- To ration demand (for example, as a means of combatting traffic congestion)
- To internalize externalities (for example, to enable road users to incorporate the social costs of their road use in their trip-making decisions)

In the early days of the development of the modern transport system, user charges were the principal source of revenue for the financing of both infrastructure and operations, for instance, the turnpikes in the United Kingdom (UK) and the United States. During the 20th century, governments commonly took on increasing responsibility for roads, viewing them as a "public good," and intervened directly in their pricing by moving to financing based on general taxation. Today, there is a diverse patchwork of approaches to the pricing of road use, and varying calls for reform.

Direct-user charges in the form of road pricing are the exception. Tolls, in one form or another, continue to be used on some major highways in some countries, while road-related taxes, such as taxes on car ownership and on fuel, are commonplace

and a major source of tax revenue. Further, there are a number of specific urban road-user charging initiatives that have been introduced as a means of rationing demand and raising revenue.

How It Works

Road pricing starts with the premise that road users will pay a charge or fee when they determine that the benefits of paying outweigh the cost and they will drive accordingly. In situations where the road users do not think the benefits outweigh the cost, they will decide to change their travel behavior to avoid the payment.

This behavior change may involve rerouting, rescheduling, grouping journeys together (for example, car sharing or trip chaining), switching from a car to another mode, or simply reducing travel. Sometimes change will occur immediately, but sometimes it may only occur over a longer period; and longer-term changes may involve more dramatic responses, such as moving a home or work location.

Urban road pricing may take a number of different forms, including "point pricing" and "area charging." Point pricing involves the levying of a price to pass a point on a road, not unlike conventional toll systems. However, a price on a single road is likely to encourage traffic to divert to avoid it, and so most point pricing systems involve cordon charging (or toll rings) in which a series of charging points are established at all entries to a given area. This concept can be extended to a series of concentric cordons, or cells, or a cordon combined with radial screen lines.

Area charging (or area licensing) is another variant of cordon charging, in which a charge is levied to use a vehicle within a defined area, rather than just to enter it. This will also control vehicle journeys wholly within the cordon, which are unaffected by cordon charging (and might, as a result, increase).

Urban Uses

The first urban road pricing scheme in the world was introduced in Singapore in 1975. Initially, this was an area licensing (area charging) scheme to reduce congestion in the city center. Drivers were required to purchase licenses (by the day or the month) to allow them to enter the defined area between 7:30 A.M. and 10:15 A.M. The initial charge was 3 Singapore dollars (\$2.36); this was raised to 4 Singapore dollars (\$3.14) in 1976.

Vehicles with four or more occupants were exempt from the fee. Enforcement was by manual inspection. Subsequent modifications involved extensions into the evening peak hours, the working day, and Saturdays; to a set of charging points on expressways, and to all cars, regardless of how many occupants they had. Different charges were levied for different types of vehicle.

In 1998, the area licensing scheme was replaced by an electronic road pricing scheme in which 97 percent of the 700,000 vehicles in Singapore were fitted with onboard units in which smart cards were inserted. Structures at the entry points and expressway charging points used in the prior system were equipped to identify, interrogate, charge, and, if necessary for enforcement, photograph, all vehicles passing.

Charges are now levied per crossing rather than per day, and vary by time of day and vehicle type. Charges are revised quarterly to maintain speeds at between 12 miles per hour (mph) or 20 kilometers per hour (kp/h) and 19 mph (30 km/h) in the city center, and 28 mph (45 km/h) and 37 mph (60 km/h) on expressways. As a result, charges are lower than they had been with the area licensing scheme for much of the day, and they have been waived on Saturdays.

In 1986, Bergen, Norway's second-largest city, was the first city in Europe to introduce a toll ring (or cordon) charging system. It was introduced with the objective of raising the finances required to accelerate the implementation of a wide-ranging program of transport investment. The system charges all vehicles (other than buses in regular service) a flat fee for entering the city's central business district and operates between 6:00 A.M. and 10 P.M., Monday through Friday.

Toll rings were subsequently also introduced in Norway's cities of Oslo and Trondheim. As in Bergen, the main objective is to raise revenue, and so charges are set according to revenue goals. Both Oslo and Trondheim use electronic toll collection, and in Trondheim, tolls are differentiated by time of day.

In 2003, London introduced an area licensing scheme known as the London Congestion Charge. This covers an eight-square-mile area of central London. (The size of the charging zone was approximately doubled in 2007 with the inclusion of an area west of the original zone, but that western

extension has since been removed from operation.) Drivers wishing to enter the zone between 7:00 A.M. and 6:00 P.M., Monday through Friday, are required to pay the Congestion Charge.

The charge was 5 pounds sterling per day (\$7.77) when first implemented, but it has since risen to 10 pounds (\$15.55). However, there are a number of exemptions, which apply to motorbikes, mopeds, taxis, buses, emergency vehicles, vehicles using alternative fuels, and vehicles whose drivers are disabled; residents of the zone receive a 90 percent discount. It is possible to pay the charge in advance on a daily, weekly, monthly or annual basis, either by phone, mail, Internet, or at retail outlets.

Entry into the charging zone is indicated by a mix of street signs and pavement markings, and enforcement is by Automatic Number Plate Recognition (ANPR), facilitated by a network of fixed and mobile cameras. A fine in excess of 100 pounds (\$155.50) is levied in cases of nonpayment, although it is halved if the fine is paid within 14 days. Implementation costs in the first two years were 190 million pounds (\$295.5 million), more than twice the amount expected, and annual operating expenses are approximately £130 million (\$202.1 million). The system has covered its capital and operating expenses every year since its inception. For example, revenues amounted to some 268 million pounds (\$416.7 million) in the year ending June 2008. All proceeds are earmarked for spending on improved transport within Greater London.

The most recent large city to introduce congestion charging was Stockholm, Sweden. A system of cordon-based variable pricing was deployed first on a trial basis, from January 2006 to July 2006, before it was made permanent in August 2007, following a close public referendum in September 2006. The system charges vehicles registered in Sweden when they pass one of 18 "control points" entering or exiting the cordon (based on the central business district) between 6:30 A.M. and 6:30 P.M., Monday through Friday.

The rates vary from 10 Swedish krona (\$1.50) to 15 Swedish krona (\$2.25), depending on the time of day, for crossing a control point. The maximum charge per vehicle per day is 60 Swedish krona (\$9.00). Exemptions from the charge are awarded to motorcycles, buses, taxis, certain alternative-fuel vehicles (ECO-cars, LPG, and electric), emergency vehicles, vehicles with disabled drivers, and foreign-registered vehicles. There are no resident discounts,

except for residents of one land-locked island from which mainland Sweden is accessible only via the cordoned area. Enforcement is via ANPR, using digital imaging cameras mounted on overhead gantries. The costs of implementation included an investment of 1.3 billion Swedish krona (\$180 million) for the tolling system, plus a massive investment of 2 billion Swedish krona (\$280 million) in related public-transport improvements.

National-Level Experience in Europe

At the level of the European Union, policy regarding infrastructure pricing for road transport largely concerns road freight traffic; the issue of pricing for the use of roads by private car is an issue left to individual member countries. Policy was initially, in the mid-1990s, aimed at limiting competitive problems within the road freight sector caused by the existence of very different methods and levels of pricing for infrastructure use in different member states. For example, vehicles licensed in a country with low annual license duty, plus supplementary tolls, may have had an unfair competitive advantage when competing with a vehicle licensed in a country with high license duty and no supplementary tolls. Thus, charges were permitted to be levied in a nondiscriminatory way on heavy goods vehicles (HGVs) wherever they were registered.

Directive 2006/38/EC revises the Eurovignette regime and represents the current legal position on European road goods vehicle pricing. The 2006 Directive allows the toll to be applied to all HGVs (vehicles weighing over 3.5 tons). It is applied to the trans-European network (TEN), but permits application of pricing to other roads as well. It is also recommended that "revenues from tolls or user charges should be used for the maintenance of the infrastructure concerned and for the transport sector as a whole, in the interest of the balanced and sustainable development of transport networks."

In terms of differentiation, the 2006 directive provides for variations according to a number of factors, such as distance traveled, infrastructure type and location, vehicle type, and time of day. Thus, prices can be differentiated to reflect the key variables determining marginal social cost. However, the legislation still ties the average charge to the average cost of building and maintaining the infrastructure, excluding externalities (except in the case of sensitive areas such as the Alps, where a

markup can be applied and used to finance alternative transport infrastructure).

In parallel with these developments in EU-wide transport infrastructure pricing policy, a number of EU member states have been examining proposals for national schemes for the pricing of heavy goods vehicles. Austria in 2004, Germany in 2005, and the Czech Republic in 2007 introduced their own distance-based road pricing systems for heavy goods vehicles using their national motorway networks. Somewhat removed from the thrust of European policy with regard to the internalization of external cost, they are based on infrastructure capital, maintenance, and operational costs, and might be seen as an alternative means of road financing, though they do incorporate some price differentiation according to environmental factors.

The one European country to have introduced charges for HGVs on all roads, which explicitly includes environmental costs, is Switzerland (not a member of the European Union). Part of these charges is earmarked for investment in new rail infrastructure.

Road-Use Pricing in the United States

In the United States, a number of road pricing initiatives aimed at tackling congestion and raising revenue have been implemented over the past two decades. Legislation in California to attract private capital to investments in new or previously programmed highway improvement projects led, in 1995, to the State Route 91 (SR 91) Express Lanes operating company implementing a variable-toll schedule, labeled as "Value Pricing."

At approximately the same time, the federal government initiated funding for a number of demonstration projects focused on using pricing to tackle road congestion, which, in 1998, it renamed the Value Pricing Pilot Program. Under these initiatives, the United States has led the way in the variable pricing of lanes; for example, variable prices are charged on separated lanes within a highway, such as express-toll lanes or high-occupancy toll (HOT) lanes.

On SR91, the variable tolls on the express lanes range from \$1.25 during off-peak times to as much as \$9.80 on Friday afternoons. Adjustments are made to the tolls every three months based on traffic observed over the previous three-month period. It is reported that speeds on the express lanes are 60 to 65 mph, compared with speeds on the adjacent

free lanes of only 15 to 20 mph, and that, in the peak periods, the express lanes can carry almost two times the number of vehicles as the free lanes.

The San Diego HOT lanes, which operate on an 8-mile stretch of I-15 north of San Diego, are typical of HOT lanes elsewhere. They allow high-occupancy vehicles (public transport vehicles and cars containing two or more people) to travel free, while single-occupant vehicles may access the lanes if they pay a variable toll (\$0.50 to \$8.00).

When it opened in 1998, the San Diego scheme became the world's first fully dynamic variable-pricing operation. The toll varies based on the congestion level, which is analyzed every six minutes, with tolls being modified as necessary. The scheme is seen as having been a clear success, and is being extended to a length of 20 miles.

HOT lanes have also been introduced in Houston, Texas, and Minneapolis, Minnesota, and express lanes in Denver, Colorado, although with less clear-cut success than appears to have been the case in San Diego. Also, variation in the pricing of existing toll facilities has been introduced under the auspices of Value Pricing, such as for bridges in the New York/New Jersey area and in Fort Myers, Florida.

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See Also: Automated Road-Pricing and Toll-Collection Systems; Cordon Travel; High Occupancy Toll Lanes; High Occupancy Vehicle Lanes; Highway Finance; Toll Roads, Private; Traffic Congestion; Traffic Mitigation Programs; Travel Pricing; Trip Reduction Programs; Value Pricing.

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Road Rage

The term *road rage* became popular in the United States in the 1990s as stories increased about drivers becoming violent against one another on the road and while stopped at intersections or parking lots. The phrase often is used interchangeably with the term *aggressive driving*, but there is no clear consensus regarding a specific, encompassing definition. Some contend that aggressive driving includes actions such as intentionally cutting off someone, driving too closely behind, or making rude gestures to another driver; road rage pumps the aggression up a notch and refers only to incidents where actual violence has occurred.

The lack of a broadly accepted definition means that road rage, in most cases, is not considered a criminal activity. Many aggressive driving maneuvers fall under the classification of traffic violations, but in very few cases is it categorized as a criminal offense. Regardless of terminology or legal status, it is clear that dangerous behavior is at the root of both road rage and aggressive driving.

There are many contributing factors and behaviors associated with road rage, but there is one main deterrent: disengagement. Refusing to let one's own emotions dictate response to a real or perceived road incident is the best way to avoid initiation or escalation of dangerous driving situations with other motorists.

Factors That Contribute to Road Rage

Driving an automobile is inherently hazardous because of the many variables that are always at play, such as weather, traffic patterns and accidents, and the actions of other drivers. Some of those actions may be unintentional, such as swerving into another lane due to a momentary distraction, but others are deliberately intended to cause anger or even to do harm. That is the case with perpetrators of road rage. They let anger build within themselves until they make irrational driving decisions designed to retaliate against a perceived vehicular-related wrongdoing by another driver or individual.

While many drivers consider the act of driving to represent individual freedom, they often overlook the fact that driving is actually a communal activity. Drivers are rarely on the road by themselves, and thus participate in a larger driving community made up of diverse drivers with varying agendas, skills, distractions, and experiences. That disassociation with others while driving plays a part in the evolution of road rage. Drivers who focus solely on themselves may perceive another driver's actions only in terms of how it affects them individually, rather than the driving community as a whole. Believing that an action is directed personally makes it much easier for emotions to evolve into anger.

Cultural views about aggressive driving do not help. In the United States, children learn early on that the regular rules regarding accepted behaviors do not always apply in an automobile. Almost everyone at one time or another has engaged in, and thus demonstrated to others, some form of aggressive driving behavior, such as speeding or changing lanes multiple times to outpace traffic. Some movies and television shows also portray aggressive driving as a norm, or even as a positive and exciting undertaking.

Other cultural views also serve to feed road rage in the United States. For example, standing up to confrontation is perceived as a favorable and courageous act. In a territorial society that also encourages taking out one's frustrations to provide personal relief, the mix provides a hotbed for festering emotions. Those emotions occasionally erupt as road rage. Road rage incidents typically occur when drivers already under stress from something in their work or home life encounter a situation that

triggers an aggressive response that is often irrational and directed at another driver or individual.

In an already tense individual, driving can add even more pressure. For example, the restricted mobility of the driver's seat hampers physical movement, and the monotony of many roadways may only add to the driver's feelings of confinement and limitation.

In addition, the sense of unpredictability and having no control over certain events, including road work, weather delays, and the actions of other drivers, may increase driver anxiety and skew objectivity in favor of misinterpretation and overreaction. The scenario often perpetuates itself in one driver's negative reaction feeding another's until the cycle escalates into active aggression based on raw emotion rather than rational reasoning.

Behaviors Tied to Road Rage

Part of the issue in determining what constitutes road rage is the lack of clearly defined parameters. There is no consensus among the public and law enforcement agencies about behaviors that can be definitively called road rage. While some drivers classify honking the car horn or changing lanes without signaling to be aggressive driving, others do not. Similarly, some drivers consider driving 10 miles per hour over the speed limit to constitute aggressive driving, but law enforcement officials generally do not.

Broadly speaking, driving behaviors that stem from impatience or inattentiveness, such as not using a signal when turning or not stopping fully at a stop sign, represent the bottom tier of aggressive driving actions. Almost everyone perpetrates this type of behavior at some point during their time behind the wheel.

The sparks of road rage begin at the next tier of aggressive driving behavior, which involves maneuvers that specifically target another driver as part of a power play or act of retaliation against a perceived malicious act. These types of activities may include purposefully blocking another car from passing or slamming on one's brakes to force another car to react. It is usually the final stage before road rage. Road rage represents the escalation of the previous stage's feelings of righteousness and retaliation, and then combining them with acts of reckless driving, such as racing, and even actual violence, including chasing or threats with a weapon.

Dealing With Road Rage

Someone whose aggression has evolved toward road rage is likely to perceive even an inadvertent or nonexistent driving error as an act of aggression toward them, triggering a dangerous driving reaction. The best way to respond to another driver's rage is to remain in control of one's own emotions and one's own vehicle. Responding with a horn, a gesture, or increased speeds likely will serve only to aggravate an already tense situation. Failing to actively engage may quash potential danger and destruction. Preventing an incident from growing protects the safety not only of the potential victim but also the raging driver, the surrounding driving community, and any law enforcement personnel who may be called to the scene.

On the other side, drivers who find their feelings starting to build toward road rage can do their own part to stave off incidents by changing their attitude toward driving entitlement and focusing on better driving habits. Those habits include allowing oneself sufficient time to get from point A to point B, and accounting for the likelihood of minor traffic delays in advance.

All drivers should avoid distractions such as phone calls or intense concentration on a work or life problem. It is also important not to drive while physically fatigued, which makes every action more annoying and every response potentially more aggressive. When an irritating scenario does arise, drivers should resist any urge to pursue the situation or engage in any retaliatory measures. Basically, self-control is essential. It will help drivers make more rational and safer decisions in the heat of anger while on the road.

Road Rage Statistics

A study of nearly 4,000 U.S. workers conducted in May and June 2012 by Harris Interactive on behalf of the careers Web site CareerBuilder.com found that distracted and angry drivers are prevalent on the nation's highways during peak commuting drive times.

According to the survey, 58 percent of commuters said they have experienced road rage, either as a recipient or a perpetrator. Nearly one driver in 10 reported having become involved in an altercation with another commuter. Road rage incidents were found to be more common among commuters with longer drive times, although those with shorter

commutes also reported experiences associated with aggressive and dangerous driving.

Among respondents with a commuting duration of 10 minutes or less, 54 percent indicated that they had occasional experiences with road rage, as did 37 percent of drivers with a commute time of less than five minutes. Incidents were slightly more common among female drivers, with 61 percent admitting to a likelihood of feeling angry or aggressive while driving, compared with 56 percent of male respondents. Younger drivers, ages 25 to 35 years, were the most likely to experience road rage based on the survey's findings.

Geographically, a 2010 study on road rage conducted by Reuters determined that the U.S. cities with the most aggressive drivers were New York City, Dallas/Fort Worth, Detroit, Atlanta, and Minneapolis/St. Paul. The city with the most courteous drivers was Portland, Oregon, followed by Cleveland, Baltimore, Sacramento, and Pittsburgh.

The driver behavior cited by 84 percent of respondents as being the most irritating and likely to cause anger and road rage was seeing another driver talking on a cell phone. Some 50 percent of drivers also cited being cut off as an instigator of road rage. Other aggravating behaviors called out by respondents included motorists driving too fast, following too closely, eating behind the wheel, and texting.

More than one-quarter of the drivers polled also indicated that they had seen other drivers performing dangerous activities such as applying makeup, shaving, and reading while driving. Among the reported reactions to such behaviors was honking a horn (43 percent), cursing (36 percent), and making a rude or threatening gesture (10 to 13 percent).

Conclusion

All drivers are responsible for ensuring their own safety, the safety of their passengers, and—to the extent possible—the safety of others on the road. As such, it is important to recognize that road rage is a choice. While road rage is certainly fed by heated emotions and stressful situations, it is not an uncontrollable occurrence.

Drivers tempted or confronted by a potential road rage situation should be aware that a single aggressive act by just one driver can trigger a chain of escalating events that could lead to deadly consequences. Accidents caused by aggressive driving

account for more than half of all vehicular fatalities in the United States.

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See Also: Automobile Accidents and Prevention; Automobile Culture; Commuting; Distracted Driving; Highway and Road Safety; Impaired Driving.

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Road Signage

Signage has long been considered an effective means of human communication and cooperation. Signs provide a range of different types of information in a way common to all, irrespective of language. Signs and symbols can communicate, among other things, rules, instructions, dangers, feelings, origins, and identities. They capture situations and specific circumstances, educate, and notify or report information to the viewer. There are different types of signage, including private signage (used by those with property interests and landowners) and commercial signage (signs to advertise businesses and services), as well as statutory road signage.

History

The word *sign* derives from the ancient Latin word *signum*, meaning sign, indication, mark, or token. Signs have been used since prehistoric times, with the first cave paintings. Later, the Romans were erecting stone columns along the roadside throughout the Roman Empire. These columns had etched on them the distance and direction from that point on the road to Rome. The stone

columns, known as milestones, are the earliest road signs.

As the network of roads developed across Europe and overland trade between Europe, North Africa, Asia Minor, China, and India increased, the need for road signage grew. By the late Middle Ages, road signs were being used for more than one direction. Multidirectional road signage had been established at intersections across Europe by the late 1400s, indicating the direction to major towns and cities.

In the United Kingdom (UK), local parishes installed guide posts (often referred to as fingerposts). These posts had one or more arms, or “fingers,” which pointed in the direction of travel to named places and included (on the finger) the distance from the post to the destination. Made usually of cast iron or wood, the poles were painted with black lead-based paint and the fingers were white or gray with black letters.

While these guideposts were predominantly established for road users, there are examples of their use for inland waterway travel. In 1697, legislation was passed giving responsibility for the installation of fingerposts to local magistrates. This was followed by the introduction of the General Turnpike Act in 1773. This act required trustees of land to install their own signage marking distances and directions to towns (and usually to London).

It was not until the 19th century, with the advent of the bicycle and later the automobile, that the utility of road signs was recognized and their prominence increased. It was the Touring Club Ciclistico Italiano (TCCI), which later became the Italian Touring Club (hereafter referred to as the Club), that devised one of the first modern-day road sign systems in the world. Led by cycling enthusiast Luigi Vittorio Bertarelli until his death in 1926, the Club sought to promote travel and tourism by advocating measures to systematize traffic and improve road signs. The Club also published maps and guides on Italy and its regions to aid tourists and visitors.

In 1900, a Congress of the International League of Touring Organizations was held in Paris to review proposals for standardizing road signage. By 1908, the International Road Congress in Rome had established the patterns for the main traffic signs. This standardization was followed swiftly by a number of other European states that agreed on the use of certain pictorial symbols, including the

signs indicating a bump in the road, a bend, intersection, and grade-level railroad crossing. The use of symbols rather than words was considered easier to see and a more effective form of communicating information at both distance and speed.

Modern Signage

Signage on the UK road network conforms generally to European norms for prohibition signs, such as danger and caution being displayed with a red border rather than the customary yellow background in the United States. The main anomalies in the United Kingdom are the provision of distances shown in miles or yards and the speed in miles per hour (rather than kilometers), and the height and width restrictions shown in feet and inches.

The present nonmotorway road signs were reformed in 1964 under the Worboys Committee. They are governed by the Traffic Signs Regulations and General Directions (2002, SI 2002, No. 3113). This legislation and its amendments together specify the design requirements—including the size, color, and type—of all road signs conveying information or warning, requiring, restricting, prohibiting, or limiting the speed of vehicles.

Signs may be of an informative, warning, or instructional nature. Instructional signs are generally circular, warnings are triangular, and informative signs are rectangular or square. Primary routes are indicated by green directional and distance signs with yellow text, and secondary roads use black text on a white background.

The Anderson Committee established the UK's present-day motorway signage system of white text on a blue background in the late 1950s and early 1960s. These distinctive British road signs, designed by Margaret Calvert and Jock Kinneir, were determined through tests to be the clearest at distance and motorway speeds of travel. While at the time the main objective of the design was safety, not style, in 2011 the London Design Museum recognized the pioneering design achievements of these signs through the acquisition of an M1 sign and other British road signs.

In the United States, a similar movement petitioning for posting signs on key roadways began in 1899 with a group of car owners who met at the Waldorf Astoria in New York to form a car club. By 1905, car clubs across the country were installing signs on main roadways, designating routes, destinations,

and distances for motorists. The Buffalo Automobile Club was the first to put up a network of signs in New York, and by 1909, the Automobile Club of California had installed signs on major roadways within a 250-mile radius of San Francisco.

Standardization of road signs was adopted in the United States in the mid-1920s. An article published in October 1925 in the *American City Magazine* outlined the introduction of standardized road signs including, detail related to the shapes, sizes, and colors as adopted by the Joint Board on Interstate Highways. These standardized road signs fall into two groups: (1) the standard route markers and (2) the danger and caution signs. The standard route markers providing directional and information signs use the shape of the official U.S. shield (the six point shield). Originally made of steel, these signs have a white background with black type.

The approved design and information to be contained on the signs for U.S. highways was described in *American Highways* in April 1927 as the “commonly known U.S. shield outline, and this shield carries the route number, as well as the State name through which the road passes.” On the hand, signs indicating danger or caution are differentiated by degree of danger through sign shape, color, and marking.

The signs have a yellow background with black letters and/or symbols. For instance, a round sign will only be found at railroad crossings, an octagonal sign will be used where a complete stop is required, and the diamond shape indicates that there is some road condition ahead that calls for the exercise of caution. The use of shapes rather than just color is to enable those who may be unable to read or are color-blind to understand and take the necessary action. The road signage system emerging in the United States in the 1960s adopted many international symbols and pictorials depicting road conditions, speed limits, and other travel information, while at the same time developing its own design style. The yellow or white background colors for U.S. road signs were considered to provide the greatest contrast with black lettering, especially in low visibility and at night.

The material used for road signs has evolved along with the signage itself. Originally made from stone or wood, the 18th and 19th centuries introduced painted cast iron and steel. In the mid-20th century, sheet aluminum with adhesive plastic coatings



Hundreds of worn metal street signs in typical U.S. styles with yellow and white backgrounds and black lettering are set aside in a scrap pile in New Orleans, Louisiana, in 2011.

began to be widely used. In the United States at this time, glass beads were being used in some signs as a means of producing a reflectorized effect at night. These beads, approximately 0.75 inch in diameter, were glued onto the sign in the shape of numbers or symbols. The development of retroreflective sheeting increased sign visibility at night. This transparent reflective film is still used for road signs today.

A new generation of road signs and signals emerged with the development of light-emitting diode (LED) lighting. The road beacon system and electronic displays enable information provided to road users to vary to reflect the road conditions and circumstances. They use intelligent technology (IT) via sensors or remote controls. Information posted on these signs can change and often includes road closures, temporary speed restrictions, current average journey times, and notifications of accidents, as well as public safety information such as missing children alerts (Amber Alerts). These road signs dispense the latest information on mobile unit

or overhead boards in a convenient way that is visible to all road users and have led to improvements in road safety.

With growing volumes of traffic, higher speeds of vehicles, more commercial traffic, and an increasingly sophisticated road network, road signs must be effective, not only in communicating the distance to and direction of a destination for ease of navigation, but, more importantly, in reducing the risk of accidents. In order to achieve this, signage is a highly scientific and technical discipline grounded in the need to ensure signs are visible, intelligible, readable, understandable, and motivate the necessary behaviors in road users.

While countries may have created design differences within the development of their road signage systems, there exists a vast uniformity in the symbols adopted that communicate information to road users. This is of benefit to accident prevention and safety as the information is easily recognized, translated, and understood by travelers and tourists in an ever more accessible and transient world.

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See Also: Automated Traffic Control Systems; Automobile Accident Avoidance Systems; Highway Aesthetics; Highway and Road Safety; Road Surface Marking and Markers; Visual Pollution.

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Road Surface Marking and Markers

"Road surface marking" refers to any type of apparatus or material used on the surface of a roadway or parking area as a means of communicating navigational, safety, and traffic enforcement messages to drivers and pedestrians. For example, road surface markings and markers are used to define lanes of traffic, deter excessive speed in certain areas, delineate pedestrian crossings, and designate parking spaces.

In the United States, the practice of road surface marking has evolved significantly from the first recorded use of a painted center line to designate lanes on a Michigan highway in 1911. Modern road surface markings incorporate the latest technological advances in terms of materials and application across all types of road surfaces throughout the country.

Most countries have their own road surface marking standards, and there is no uniformity across international borders. Broadly speaking, however, road surface markings worldwide fall into three main categories: mechanical markings, non-mechanical markings, and temporary markings.

Mechanical Road Surface Markers

Mechanical road surface markers are generally raised or recessed into the road surface and may be reflective. Most mechanical markers are permanently installed, although they can be moved or modified based on needs and capabilities. The main types of mechanical road surface markers in the United States are "Botts' dots" and rumble strips.

Botts' dots are named for the California engineer Elbert Botts, who invented the epoxy that keeps the raised white half-spheres secured to the road surface. Botts' dots are low to the ground and are non-reflective. They are used most frequently to delineate the edges of traffic lanes and are sometimes used across travel lanes to keep drivers' attention on the road. In addition, this type of road surface marker is used to make drivers aware of school zones, upcoming toll booths, and significant speed limit restrictions.

Because Botts' dots are raised off the road surface, they are not as suitable for road surface marking in regions where snow plows are used regularly

to scrape roadways for snow removal. Another marking device known as a “cat’s eye” takes snow plowing into account. It is made up of four reflective lenses mounted in a durable white rubber housing that is mounted into a cast-iron form. The rubber housing sinks into the form when a vehicle moves over it, providing a relatively smooth surface for plows to pass over. A self-cleaning mechanism wipes the lenses each time the device is depressed. This type of marker is used widely, but mainly in Great Britain and Ireland.

“Rumble strip” refers to a series of shallow channels that are ground out of the pavement on a roadway to create a vibration and intonation when a vehicle passes over it. The vibration and sound are intended to alert the driver about approaching hazards or areas that require reduced speed and caution. Raised strips that are adhered to the road surface serve a similar purpose, creating a vibration and sound when a vehicle passes over them to warn the driver.

Road surface markers that have reflective surfaces are commonly used as lane dividers and to indicate exit and on-ramp access roads. The incorporation of a raised retroreflective element into the marker makes it more easily visible in the dark and in inclement weather circumstances, such as driving rain or snow.

Reflective road markers in the United States tend to be installed to appear white to drivers proceeding in the proper direction and red to those who are traveling against the intended direction of traffic flow to provide an extra visual warning of potential danger.

Reflective markers, which are alternatively known as raised pavement markers or road studs, also can be used to identify the location of fire hydrants or other stationary resources for use by emergency service vehicles or to identify pedestrian crosswalks. In addition, reflective markers are occasionally used at the entrances to gated communities to indicate a barrier to through traffic or the site of a code-entry device to open the gate.

In colder climates subject to snow and regular road clearing, reflective markers are often installed below the road surface and appear as an elongated narrow triangle to drivers on the road. Technological advances have enabled raised reflective markers to be installed above the road surface by incorporating rails that protect the reflective

components of the marker from being damaged by the blades of snow plows.

Nonmechanical Road Surface Markers

In addition to mechanical road surface markings, which are typically raised or recessed from the driving surface of the road, several nonmechanical approaches exist that provide flexible, cost-effective options for marking road surfaces. The most widely used nonmechanical markers include the use of paint, plastics, thermoplastic binders, or epoxy.

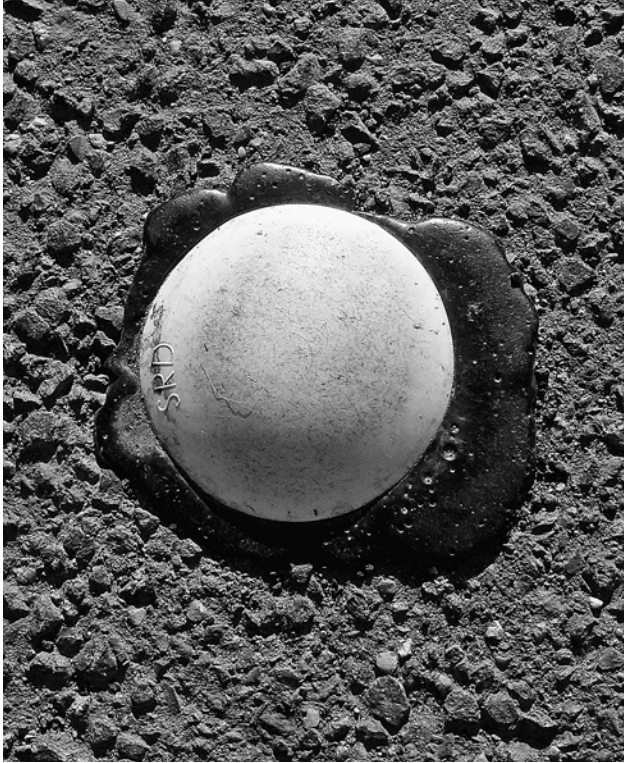
Paint is a low-cost method for road surface marking. It is widely used to designate travel lanes, delineate the borders of parking spaces, and indicate loading zones. Sometimes an additive, such as tiny glass beads, is included in the paint to create a more reflective surface for better visibility. Painted markings are typically applied by a specialized “striper” truck that disseminates the paint in a controlled manner immediately following the laying of the pavement as part of road construction or maintenance. Symbols other than lines that are painted on roadways and parking lots, such as arrows indicating turn lanes and diamonds identifying high-occupancy-vehicle lanes, are usually applied manually using a stencil template.

Plastic tape, often embedded with reflective components, is another commonly used method for marking road surfaces. It functions as a strong, cost-effective material to mark pedestrian and railroad crossings, bicycle paths, and lanes dedicated for use by high-occupancy vehicles such as multiple-passenger commuter cars, taxis, and buses. The plastic tape can be adhered to the road surface using industrial-grade rubber cement, which lasts about three years, depending on the region.

For example, in areas where snow plows, salt, or sand are used to remove ice and snow from roadways, the tape and binding agent can wear more rapidly. Plastic tape also can be inlaid into the pavement itself using a heating and hardening process.

Thermoplastic road markers take the use of plastic-based markings one step further. Thermoplastic coatings are generally in the form of a dry mix comprised of binder resins, plasticizers, glass beads or other reflective components, white or yellow (and sometimes red) color pigments, and fillers.

They offer improved durability and sustained reflectivity compared to paint and plastic tape markings, but they require more up-front cost



A "Botts' dot," named for engineer Elbert Botts, is affixed to a road in Australia. Botts' dots are used to delineate traffic lanes, school zones, toll booth approaches, and speed limit changes.

and specially designed vehicles to heat and apply the thermoplastic mix to the road surface.

Initial reflectivity occurs at a second stage of application, when glass beads are embedded into the smoldering mix just after it is put on the road and before the plastic hardens. Long-term reflectivity takes place once the surface layer is worn off, uncovering the beads or other reflective component originally mixed in with the binder blend. Many common applications of thermoplastic road markers involve preformed and precut devices that are used to demarcate intersections, stop lines, crosswalks, and bicycle lanes. They also are used frequently to create directional arrows and access symbols.

Epoxy offers an affordable alternative to paint and plastics for use in road surface marking. It is created through a chemical process that results in a resin that reacts with certain chemicals to form a hardening or curing agent that is very strong and resistant to high temperatures, high traffic, and chemical degradation. When applied to road surfaces, epoxy provides durable striping.

Temporary Road Markers

Temporary road markers are used to supplement more permanent mechanical and nonmechanical markings. They are used largely for construction and maintenance activities or to indicate temporary traffic diversions necessitated by large public events, such as a marathon, or by safety situations resulting from accidents or flooding.

Temporary markers also can serve as placeholders for more permanent marking methods that will subsequently be applied or to alter traffic patterns that follow a consistent change schedule. For example, temporary road markers can be used to direct two-way traffic into a one-way pattern around a school to accommodate student drop-off and pick-up at specific times during the week.

Road surface markers that are temporary in nature include removable signage, pylons, and barricades. Sometimes paints and plastic tape are used for short-term road marking. Temporary road markers can be reflective or nonreflective, depending on needs.

Common U.S. Road Surface Markings

Standards for road surface marking in the United States are set and enforced by the U.S. Department of Transportation's Federal Highway Administration and are published in the *Manual on Uniform Traffic Control Devices*. While specific applications and materials for markings may vary by and within each state, white markings are generally used to indicate division of lanes in which traffic travels in the same direction, and yellow markings are used to signify separation of lanes in which traffic flows in the opposite direction on either side of the surface stripe.

A single dashed line is universally understood across the United States to mean that passing or changing lanes is permitted. A single solid stripe indicates strong discouragement for passing and changing lanes, while a double solid line signals that passing and changing lanes are legally prohibited. In cases where there is a double white line with one side featuring a solid stripe and the other side sporting a dashed line, the message for U.S. drivers is that passing is permitted from the lane of traffic with the dashed line but is not allowed from the lane on the side with the solid line.

Solid lines are also used to delineate the outside edge of the pavement from the shoulder of the road. Right-edge lines are marked with a solid white line

and should always be on the passenger side of the vehicle, while left-edge lines are marked with a solid yellow line and should be on the driver's side of the vehicle. A stop line is a wide white line that spans the applicable lanes perpendicular to traffic. Road surface markings for pedestrian crosswalks take the form of either two parallel solid white lines that cross the line of traffic on a roadway or two parallel solid white lines punctuated with perpendicular internal white stripes, which may be used on larger roads.

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See Also: Automobile Accidents and Prevention; Bikeways/Bike Lanes, Road Design Issues of; Busways and Reversible Bus Lanes; Highway Construction and Maintenance; Intersections; Road Signage; Street Design/Patterns; Traffic Control Devices.

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Roadside Assistance Programs

Despite escalating costs of fuel (gas prices nearly doubled in the first decade of the 21st century), the American transportation network is still defined largely by vehicular travel, and that travel system only works when vehicles are reliable and able to run. In a country with more than 250 million vehicles that travel on more than 4 million miles of roads, the possibility for unanticipated engine failure or catastrophic breakdowns along busy highways or in remote or unfamiliar areas exponentially increases. Given that current American Automobile

Association (AAA) data suggest that car owners are now more likely to hold on to older cars in the face of economic uncertainties (the average age of on-road vehicles in the United States is just over 11 years), vehicular breakdowns have become a significant concern and have occasioned, in the era of wireless communication, a wide range of cutting-edge, 24/7 roadside assistance programs designed to not only provide vehicle owners with speedy and reliable repair service but also help maintain unimpeded traffic flow critical to the nation's massive highway system.

The principle behind roadside assistance programs is simple—most car failures are caused by basic problems, many of them the consequence of bad luck or simple carelessness. These programs can be traced to the early 20th century. During the initial automobile craze, car owners, then relatively few, made up a kind of exclusive club in cities. There were few garages and even fewer mechanics. Car owners were often the best equipped to address car problems. As a consequence, they would maintain unofficial networks of close communication neighborhood to neighborhood (long-distance driving was still impractical). Owners would know each other and, should they be near a telephone, could summon help when their cars would suddenly stop or overheat or tires would blow out or if they simply got lost.

Postwar Growth

After World War II, as part of the massive suburban expansion when car usage spiked sharply, suburban commutes as well as interstate and even cross-country travel became the norm. Roadside assistance programs evolved to meet that challenge. But the operating concept of such programs was still simple enough: if the car problem was basic, get the car back on the road; if that was not possible, tow the car to the nearest available garage.

Rather than relying on informal Good Samaritan groups among a small coterie of car aficionados, now major companies, most prominently motor clubs/travel agencies such as AAA and insurance companies (most notably, in the beginning, Allstate) developed programs for which car owners could pay a set annual fee to insure that, in the event of any number of relatively minor roadside problems, assistance could be arranged quickly and safely. To accommodate the services, these same companies

pioneered placing emergency call boxes every few miles along the most heavily traveled roads.

Roadside assistance programs were never designed as part of any post-accident response, nor to assist in the event of medical emergencies involving the driver or passengers. Rather, they dealt with a range of vehicular problems. As these programs developed, the kinds of problems covered grew as companies vied for the steadily increasing market of vehicle owners during the 1960s when America's love of the automobile flourished in the age of cheap gas. Although initially most roadside assistance programs simply provided help for motorists stranded with a dead battery or a flat tire, over time the programs also offered services for cars that had run out of gas (delivering up to three gallons) and/or engines that needed critical engine coolants or motor oil.

Services were extended to help retrieve keys from locked cars. In wintry weather, roadside assistance programs would offer to pull out vehicles stranded in snowbanks. Insurance agencies described such events as both unanticipated and inevitable, whatever the diligence and care of the driver. In each case, the critical work could be done right off the highway—only in extreme circumstances would the car need to be towed, as that would most likely strand the owner. In such cases, many of the programs provided help in finding hotel accommodations and, in the most extreme cases, help in securing alternate transportation.

Unlike far more expensive comprehensive breakdown recovery programs, insurance programs geared to assist in towing cars with catastrophic engine failure as quickly as possible to a garage (the preferred roadside assistance programs in the United Kingdom and in Europe, where highway transportation is far faster and more dangerous than in the United States), roadside assistance programs are geared to help with problems that, while not critical, are nevertheless vital to the car's operation. Roadside assistance programs can assist drivers who are still in their driveways.

Given that relatively rare instances of simple bad luck or embarrassing recklessness are chiefly responsible for most roadside assistance program incidents, drivers buy into the coverage—usually an annual fee somewhere between \$35 and \$100 depending on the range of services covered—essentially for peace of mind. AAA data indicates that in

2012, for instance, less than 28 percent of those with roadside assistance coverage actually used it. But programs have proliferated. Over the last generation, roadside assistance programs have been developed not only by insurance providers and travel agencies but also by car manufacturers who provide programs for new car owners as part of purchase incentive packages. Oil companies and service plazas advertise roadside assistance programs. Even credit card companies and cell phone providers use roadside assistance packages to attract customers.

In 2012, Walmart introduced a modified program as part of its garage service. In many rural areas, church groups and other volunteer civic organizations do the work of roadside assistance, their services advertised on billboards and through Internet information services. The revolution in wireless communication systems has created an entirely new generation of roadside assistance software—OnStar, for instance, can provide garages within the calling range the exact location of a stranded car. Roadside assistance programs now extend to RVs, motorcycles, watercraft, and even bicycles. Data collected by AAA suggest that more than three-quarters of car owners who must drive more than 150 miles a week have some form of roadside assistance insurance.

Criticisms

Given the wide range of highway systems and given the sheer number of vehicles prone to needing assistance around the clock and given the wide array of businesses offering variations of roadside assistance, the service is not uniformly efficient. In theory, the roadside assistance program chosen by the driver provides a toll-free number from which, in turn, local emergency field representatives would be dispatched in a timely fashion. Customer service online review forums, however, are replete with alarming stories of wait times for emergency assistance vehicles that often extend for hours, leaving the driver stranded in unfamiliar environments and compelling them ultimately to use their cell phone to arrange alternative help.

Professional garage mechanics are quick to point out that given the kind of cut-rate speedy service offered, it is not unusual for unscrupulous assistance providers to take advantage of drivers in dire circumstances. Representatives dispatched to the site often lack critical engine knowledge and repair

skills (and sophisticated mobile engine malfunction diagnosis equipment) to work efficiently with modern engines that are often delicately set to computer-driven systems. The “repair” they offer is at best a temporary fix that can give false reassurance to the vehicle owner, as the on-site mechanics are unwilling (or unable) to perform deep engine diagnoses such as checking the belts or tire pressure, making electrical repairs, testing air cooling systems, or analyzing brakes—the kind of checks done routinely in a full garage tune-up. Rather, now as a first resort, they tow because that is the easiest response. Towing itself, of course, puts enormous additional strain on a vehicle.

Conclusion

But even with those caveats, given the tight monitoring by travel agencies and insurance providers inevitable in a very competitive market susceptible to online reviews, roadside assistance programs are still one of the most notable achievements of the automobile age. Of course, the simplest way to avoid requiring roadside assistance is to be careful and to follow basic maintenance schedules suggested by car manufacturers. Despite the increasingly sophisticated computer-driven technologies in car engines, the problems addressed by roadside assistance are largely basic car upkeep procedures, although insurance providers point to other factors, including poor driving habits, ill-advised driving risks, the use of cheap fuel, and the owner’s failure to heed warning lights on the dashboard that track critical engine requirements (oil and coolant as well as tire pressure). Until cars do not require owner effort to maintain operation, participation in roadside assistance programs is viewed as not only essential but common sense.

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See Also: Automobile Culture; Automobile Safety Systems; GPS, Automobile; Highway and Road Safety.

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Roundabouts and Traffic Circles

A roundabout is a refinement of a street pattern called the traffic circle or rotary. Both traffic circles and roundabouts are replacements for a traditional intersection and force traffic to move in a circular pattern, while allowing drivers to make a turn onto another street or continue on the same street from which they entered the intersection. Traffic circles have been in use since at least the early 20th century, while roundabouts were developed in the 1960s to overcome some of the problems with traffic circles. Roundabouts have been shown to reduce traffic speeds and accidents as compared to traditional intersections and tend to become popular once people become accustomed to them.

History

The first traffic circle in the United States was constructed in New York City in 1905. Located at the southwest edge of Central Park in Manhattan and designed by William Phelps Eno, it features a large monument to Christopher Columbus in the center of the circle and hence is called Columbus Circle. Many similar, large-scale circles (often with a diameter of more than 300 feet) were constructed in other U.S. and European cities, but they proved to have several problems that made them fall out of favor by the 1950s. In these early traffic circles, entering vehicles had the right of way, and this encouraged people to drive at high speeds (often above 30 mph) in the circle, leading to frequent high-speed collisions. In addition, the circles tended to become congested, so that they sometimes impeded the flow of traffic rather than facilitating it.

In the United Kingdom (UK), a rules change in 1966 that gave priority to vehicles already in the circle acted to reduce recurrence of both of these problems—requiring vehicles entering the

traffic circle to yield to those already in it discouraged high-speed entry and reduced the number of crashes, and also helped reduce congestion within the circle by forcing vehicles to wait for gaps in traffic before they could enter. At about the same time, traffic engineers began designing smaller traffic circles, called roundabouts, that also required entering and circulating vehicles to travel more slowly. These improvements in safety made the roundabout a popular intersection design adopted all over the world, although the United States is a fairly late adopter of this design.

Design

Although each roundabout should be designed to meet the needs of a specific situation, taking into account factors such as the volume of traffic expected, the size of vehicles expected to use the roundabout (for example, buses, semi-trailers) and the amount of space available, there are certain commonalities to each roundabout. A typical roundabout replaces an intersection, so multiple roads will approach the roundabout. Around the point where the roads would otherwise intersect, there is a large circular traffic island, often landscaped to alert drivers to the existence of the roundabout. Surrounding this island is a circular roadway; traffic moves in a counterclockwise direction in right-drive countries like the United States, and in a clockwise direction in left-drive regions like the UK.

Each of the roads will have a splitter island (separator island) or median dividing traffic into entry and exit lanes and alerting drivers to the existence of the roundabout. Exit lanes are typically wider than entry lanes to minimize congestion from cars slowing to exit, although this must be balanced against the need for pedestrian access and safety. If truck use is anticipated, the central island usually includes a traversable truck apron, a wide, sloped and slightly raised (for example, 2 to 3 inches off the ground) ring around the island to give trucks additional road space, while being sufficiently elevated to discourage cars from using it.

Pedestrian crosswalks are usually located so that they cross the roads leading into and from the roundabout at least 20 feet upstream of the entrance, to discourage vehicles from blocking the crosswalk while waiting to enter the roundabout. To facilitate wheelchair access, the curbs should have

sidewalk ramps, and the splitter islands should be cut through at the same width as the crosswalk; this last feature provides guidance to people with visual difficulties as well. Planters, railings, and other features can also help orient both sighted and visually impaired pedestrians to the location of the crosswalk. The slower (12 to 20 mph) speeds typical of traffic in a roundabout are similar to typical speeds of bicycle travel, so bicycles can use a roundabout similarly to automobiles.

Advantages and Disadvantages

The most important advantage of roundabouts is safety. A recent study by the Insurance Institute for Highway Safety (IIHS) of intersections where traffic lights and stop signs had been replaced by roundabouts found that the roundabouts showed a reduction of 37 percent for overall collisions, 40 percent for pedestrian collisions, 75 percent for injury collisions, and 90 percent for fatal collisions. Notably, the greatest reductions were for the most serious collisions, a result attributed to reduced driver speed upon entry to the roundabout, the necessity to yield to traffic already in the roundabout, and the lack of possibility for head-on, left-turn (right-turn in left-drive countries) and “T-bone” or right-angle collisions, because the traffic pattern never presents the conditions for those types of collisions.

The fact that traffic flow is continuous and there are no traffic lights also means that there is no incentive to speed up, as drivers often do when approaching a traditional intersection in order to “beat the light,” a behavior that not only increases the vehicle’s speed but also takes the driver’s attention away from the traffic conditions.

Roundabouts are also an efficient way to move traffic, because they promote a continuous flow rather than requiring one lane of traffic to stop even if there is no cross-traffic, as traffic signals and stop signs do. A study by researchers from Kansas State University found that in comparing traffic flow at intersections before and after installation of a roundabout, delays were reduced 20 percent with the roundabout as compared to the traditional intersection. Other studies by the IIHS found reductions of 56 percent in vehicle stops and 89 percent in delays.

Roundabouts have several other advantages as well. Unlike traffic lights, they function equally well if there is an interruption in power, as often happens after a weather emergency, because the



Columbus Circle in New York City, seen through a window in the Time Warner Center, was the first traffic circle in the United States when it was built in 1905. Early traffic circles like this one led to speeding and numerous accidents when drivers had the right of way upon entering the circle. Rule changes giving drivers already in the circle the right of way helped reduce these accidents, as did new designs for smaller circles, known as roundabouts.

traffic is controlled by driver behavior rather than by traffic lights. Roundabouts are also less expensive than traffic signals, because while both options have similar costs of installation, a traffic signal typically costs \$5,000 to \$10,000 per year in electricity and maintenance, while a roundabout incurs neither of these expenses. A roundabout may also have a smaller footprint, because although the traffic circle is often larger than a typical intersection, the reduction in delays and vehicle stops may mean that fewer traffic lanes are required leading up to the roundabout as opposed to leading up to a traditional intersection.

The principal disadvantage of roundabouts is that many people, particularly in the United States, are unfamiliar with them and do not know how to use them safely. Because roundabouts came fairly late to U.S. traffic engineering, and are not used in all

parts of the country, many people did not encounter a roundabout when they were learning to drive and may be anxious or resistant when encountering them. This means that when roundabouts are being added to traffic patterns, public education is necessary to familiarize people with this design and to teach them how to drive safely in roundabouts.

Another disadvantage is that roundabouts do not provide the aural cues many visually impaired people use to determine when it is safe to cross the street. Because traffic never ceases, and there are no traffic signals, it may be difficult to know when the road is clear and it is safe to cross. Unfortunately, drivers do not always yield to pedestrians, not even blind pedestrians.

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See Also: Highway Interchanges; Pedestrian Safety; Pedestrian-Friendly Design; Traffic Calming; Traffic Engineering; Traffic Flow; Traffic Safety and Risk Assessment.

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Route Assignment Models

Route assignment, also commonly referred to as traffic assignment or route choice, is the problem of allocating a given set of trips (commonly referred to as demand) to a specific transport network or system (referred to as supply). The input required for the route assignment is comprised of

the supply (a complete description of the transportation system) and the demand (a matrix of interzonal trip movements, known as an origin-destination, or OD, matrix).

The output of a route assignment process is comprised of the allocation of vehicle volumes and costs (mainly in the form of travel times) on each link (defined as the connection of nodes within a transport network), under equilibrium conditions. Various models have been developed for solving the spatial distribution of trips in the network in order to achieve equilibrium.

Route assignment is the fourth step of the four-step conventional forecasting model. The first three steps are trip generation, trip distribution, and mode choice. Trips' origins and destinations are generated in the first and second step, respectively, while the mode with which each trip is conducted is estimated in the third step. Once the origin, the destination, and the mode are chosen, the routes followed by the users traveling in a transport network are calculated in the fourth step, solving the so-called traffic assignment problem (TAP).

Definitions of Network Equilibrium

The first reference to minimizing individual travel times was stated in 1841, but it was not until the late 1910s, when the subject of route choice over a two-route road network was examined. In 1924, the economist Frank Knight developed the argument that forms the basis of traffic equilibrium: he presented two highways connecting two terminals, one broad enough to accommodate a large number of vehicles but poorly graded and surfaced, and the second one with much better quality but with limited capacity. He stated that the trucks operating between the two terminals will tend to distribute themselves between both roads in such proportions that the cost per unit of transportation will be the same for all trucks on both routes. He concluded that the congestion created in the road with the limited capacity will reach the level at which both roads will be equally profitable.

In 1951, John Nash published the expected flow of traffic in a network, using the Nash equilibrium concept he developed within the game theory framework. He proved the existence and uniqueness of the equilibrium solutions.

In 1952, John Glen Wardrop stated two formal principles of the concept of equilibrium:

- *First principle.* The journey times on all the routes actually used are equal, and less than those that would be experienced by a single vehicle on any unused route.
- *Second principle.* At equilibrium, the average journey time is at minimum.

Various alternative definitions have been presented for the first principle. Let r and s be two different used routes in OD pair (p, q) , let h be the path-flow vector that contains the flow on each path for all the OD pairs, let D_{rs} be a path-shifting flow vector of the same dimension as h , which is zero in every position except those corresponding to the routes r and s , where the values of the vector are minus 1 and 1, respectively.

Equilibrium. The flow is a Wardrop equilibrium if, for each driver, the present cost on any alternative route is at least as great as the cost on his/her present route:

$$(C_{pqr}(h) \leq C_{pqs}(h)).$$

User-optimized. The flow is user-optimized if any driver who changes to an alternative route will experience a cost that is at least as great as the old one on his/her old route:

$$(C_{pqr}h \leq C_{pqs}h + \epsilon D_{rs} \forall \epsilon \in (0, h_{pqr})).$$

Equilibrated. The flow is equilibrated if any driver who changes to an alternative route will experience a cost that is at least as great as the new one on his/her old route:

$$(C_{pqr}(h + \epsilon D_{rs}) \leq C_{pqs}(h)).$$

The difference between user-optimized and equilibrated flows is characterized by the perception of cost by drivers. In the first definition, each driver is continuously aware of the cost on all routes, while in the second definition, the driver has only the information related to his own experience.

The current definition of network equilibrium was redefined in 1969, when researchers used the terms *user-optimized* (UO, or user equilibrium, UE) and *system-optimizing* (SO) to describe Wardrop's first and second principles, respectively.

These two principles have been used by all authors dealing with traffic assignment. The properties of equilibria have been reformulated as variational inequality problems, nonlinear complementarity problems, and fixed-point problems.

Definition of TAP

The problem addressed in traffic assignment is to allocate the OD flows to various routes according to the hypothesis that users try to minimize their travel cost, and making the assumption that the cost of each link is known in advance by all users. Two problems can arise in the TAP, depending on the Wardrop equilibrium definition adopted, either the system optimum TAP or the user equilibrium TAP. The second one is the most commonly used by transport planners and managers. The formal mathematical formulation is the following:

Consider a road network consisting of nodes $i \in N$ and links $a = (i, j)$. The set of origin nodes is P and the set of destination nodes is Q . Origin-destination (OD) flows between pairs of nodes are represented by dpq , where $pq \in C$ is the set of origin-destination pairs. A link flow from node i to node j is designated by fij and a link flow specific to a given origin-destination flow from p to q is designated $fijpq$. Accordingly, $fij = (pq \in C)fijpq$.

Conservation of flows of vehicles through nodes of the network is specified by three cases, depending upon whether the node is an origin $p \in P$, a destination $q \in Q$, or a simple intersection $i \in N$ of links:

$$\begin{aligned} j \in A_p f_{ijpq} - h \in B_p f_{hijpq} &= +dpq, \forall p \in P \\ j \in A_q f_{ijpq} - h \in B_q f_{hijpq} &= -dpq, \forall q \in Q \\ j \in A_i f_{ijpq} - h \in B_i f_{hijpq} &= 0, \forall i \in N \end{aligned}$$

where A_i is the set of nodes connected by links pointing out of i (after i), and B_i is the set of nodes connected by links pointing into node i (before i).

The first condition states that the net outflow at node p , which corresponds to the total flow from p to q , must equal $+dpq$. Likewise, the net outflow at node q , which corresponds to the negative of the total flow from p to q , must equal minus dpq . For all other nodes, total inflow equals total outflow.

The OD flow dpq , or demand from p to q , is determined by a function $dpq = gpq(tpq)$, which is assumed to be positive and strictly decreasing, and therefore is invertible, so that $tpq = gpq^{-1}(dpq)$, where tpq is the minimal route travel time from

origin p to destination q . The link travel time $t_{ij}(f_{ij})$ is a nondecreasing function of the link's own flow f_{ij} . Given this description of OD flows, the authors proposed to maximize the following function:

$$pq \in C_0 dpqgpq - 1 sds - ij \in A_0 f_{ij} t_{ij} sds$$

Or, to minimize the following function,

$$\begin{aligned} \text{Min } z &= \sum_{a \in A} f_a c_a w_d, \\ f_a &= \sum_{r,s} p_{rs} \delta_{a,rs} \quad \forall a \in A, \\ p_{rs} &= q_{rs} \quad \forall r \in R, s \in S, \\ h_{rs} &\geq 0, \\ \delta_{a,rs} &= 1, \text{ if a path } p \text{ passes arc } a, 0, \text{ otherwise} \\ \text{where,} \\ A, R, S &\quad \text{network's arc, origins and} \\ &\quad \text{destinations respectively} \\ Z &\quad \text{the value of the objective function} \\ f_a &\quad \text{total flow on arc } a \\ C_a f_a &\quad \text{cost of traveling arc } a \text{ when it} \\ &\quad \text{carries flow } f_a \\ h_{rs} &\quad \text{flow on path } p \text{ from origin } r \text{ to} \\ &\quad \text{destination } s \\ q_{rs} &\quad \text{demand on pair } rs \end{aligned}$$

Models for the Route Assignment

Two approaches for solving the route assignment or TAP were proposed during the 1950s: diversion curve assignment between two possible paths, and all-or-nothing assignment. The first method shifts the traffic to various paths, while the second method assigns all the interzonal traffic to the shortest path.

After the formal introduction of network equilibrium by Wardrop, various models have been developed for achieving equilibrium. W. Prager described in 1954 a formulation of the network equilibrium problem using a linear function for the estimation of the link travel time, and describing equal journey times of routes in terms of the differences in potentials at nodes of the networks, but without clarifying the source of the flows.

A. Charnes and W. Cooper proposed in 1958 a traffic network equilibrium formulation for the case of fixed origin-destination flows, but without specifying any actual impedance function.

M. Beckmann, C. B. McGuire, and C. B. Winsten proposed in 1956 the first constrained convex optimization formulation for the user-equilibrium assignment problem with elastic demand, considering the number of trips between each zone to be a

function of the travel time. They presented the first complete mathematical formulation of the first Wardrop's using link cost functions that increase with the flow on the links. They demonstrated that maximizing this function with respect to the demand and the flows, and subject to the above constraints, then, all used routes from node p to node q will have equal travel times, and no unused route will have a lower travel time.

M. Frank and P. Wolfe developed in 1956 an algorithm for solving quadratic programming problems with linear constraints. They proposed an iterative procedure, where in each iteration a sub problem was solved: the minimization of the linearized objective function by assigning all traffic to minimum-cost routes where link costs were determined by the link flows of the current solution of the main problem.

The new solution of the main problem was obtained by minimizing the original objective function by using a linear combination of the current solution and the solution of the subproblem. Since the objective function was evaluated using aggregated link flows only, path-based information was not available. The representation of the solution was link-based, resulting in low memory requirements, which is the main advantage of the method. The main drawback of the method is the slow convergence rate. The first application of a method for solving the route assignment problem was the route-based method proposed by S. Dafermos in 1968 and implemented by Gibert in the same year. In this method, flows are shifted from the maximum-cost route to the minimum one for each OD pair until both routes have the same cost.

L. J. LeBlanc, E. K. Morlok, and W. P. Pierskalla proposed the use of the Frank and Wolfe algorithm for solving the formulation proposed by Beckmann, McGuire, and Winsten, and tested it by using the traffic networks of Sioux Falls, South Dakota, which became an internationally well-known network for testing and benchmarking solution algorithms.

L. Dickson stated in 1977 the Wardrop's criteria as the finite-dimensional variational inequality problem below.

$$F x^* T \cdot x - x^* \geq 0, \forall x \in K,$$

where F is a given continuous function from K to R^n , K is a given closed convex set, and the objective is to determine $x^* \in K \subset R^n$.

Table 1 Link-, path-, and origin-based and LUCE algorithms

Link Based	Path Based	Origin Based
Decision variable		
Link flow	Path flow	Origin-based link flow
Information		
Minimum	Richest	Richest
Memory requirement		
Lowest	Highest	Medium
Convergence speed		
Low	Fast	Fast
Main categories		
Frank-Wolfe algorithm (Frank and Wolfe, 1956) Improved FW algorithms (Powell and Sheffi, 1982; Fukushima, 1984; Weintraub et al., 1985; LeBlanc et al., 1985; Lupi, 1986; Florian et al., 1987; Arezki, 1987; Arezki and Van liet, 1990; Daneva, 2003.) (RSD) Restricted Simplicial Decomposition algorithm (Hearn et al., 1985) (NSD) Nonlinear Simplicial Decomposition (Larsson and Patriksson, 1997)	(DSD) Disaggregate Simplicial Decomposition algorithms (Larsson and Patriksson, 1992) (GP) Gradient Projection algorithm (Jayakrishnan et al., 1994; Sun et al., 1996; Chen et al., 2002)	(OBA) Origin-based Algorithm (Bar-Gera, 1999, 2002) (NOB) Improved Origin-based Algorithm (Nie, 2008) Algorithm B (Dial, 1999,2006) (TAPAS) Traffic Assignment by Paired Alternative Segments (Bar-Gera and Luzon, 2007)
Observations		
The latest Conjugate/Bi-Conjugate FW algorithms appear comparable with origin-based algorithm in speed and accuracy.	Gradient Projection algorithm shows more advantages in small to medium-sized networks.	Algorithm B and TAPAS show much better performance than Bar-Gera's origin-based algorithm.

Dafermos proposed in 1980 a computational algorithm based in these variational inequalities. Smith presented in 1984 an alternative formulation of TAP, based in variational inequalities and formally proved the existence, uniqueness, and stability of the solution.

Y. Sheffi presented in 1985 a fundamental traffic assignment methodology, and the current formulation for the UE and the SO TAP.

UE: $\min x = a_0 x + a_w d_w$

SO: $\min x = a x + a_t(x)$

$k f_{krs} = q_{rs} \forall r, s$

$f_{krs} \geq 0, \forall k, r, s$

$x_a = r s k f_{krs} \delta_a, krs \forall a$

where,

q_{rs} is the OD matrix

x_a and t_a flow and travel time in link a respectively

f_{krs} the flow from r to s on path k

R. Jayakrishnan, W. T. Tsai, and J. N. Prashker introduced in 1994 the path-based algorithm, using the gradient projection in order to find the minimum of a Newton approximation of a transformed objective function. The gradient direction is calculated with respect to the flows on the non-shortest

paths while the step is found using second derivatives with respect to these flows, converging 10 times faster than the Frank and Wolfe algorithm. The drawback of this method is the large memory requirements for storing all the used paths.

R. Dial proposed in 2006 a path-based methodology for solving TAP, which eliminated the need for path storage, called Algorithm B. M. Florian presented in 2009 a revised version of the projected gradient method for equilibrium originally proposed by Jayakrishnan.

H. Bar-Gera proposed in 2002 the origin-based algorithm, where he defined the variables as an intermediate way between links and paths. He stated that the equilibrium of each origin is an acyclic graph, restricting the solution space to acyclic routes. This new methodology reduced significantly the computational effort, keeping the memory requirements to an intermediate level between the link-based and the path-based algorithms.

G. Gentile presented in 2009 a new algorithm named linear user cost equilibrium (LUCE), which achieves a very high convergence speed, because it assigns the demand flow of each OD pair on several paths at once instead of the all-or-nothing assignment used in all the other methods.

Comparison of Link-, Path-, and Origin-Based and LUCE Algorithms

The link-based algorithms use the conventional Frank-Wolfe method, which has been developed for solving linearly constrained quadratic programming problems, for solving the TAP optimization problem, with convex objective function and linear constraints. They iteratively reduce the gap between the best found lower bound and the upper bound from the last iteration until the stopping criteria are satisfied. Various improvements have been proposed for increasing the performance of the Frank-Wolfe algorithm, such as modifications in the step size or the search direction.

The path-based algorithms use the gradient projection algorithm used in computer communication networks. In this kind of network, path-flow solutions are essential for optimal flow routing, but they are usually smaller, being much more efficient than path enumeration in the road networks. The direction of search in the minimum of a Newton approximation of a transformed objective function, which includes the demand constraints,

is the non-negative constraint, the only one to be respected.

The origin-based algorithms consider flows from each origin separately, interacting on the network through mutual congestion effects. The algorithm splits the problem into the selection of the used links and the quantification of the flow assigned to each link. Table 1 presents the most significant insights of each type of model, as well as the developed models of each category.

The LUCE algorithm solves a deterministic equilibrium for the local route choice of users directed toward the same direction in each node for defining the descent direction search, instead of solving multiple shortest-path problems. The network is loaded through the corresponding splitting rates, avoiding explicit path enumeration, and assigning the flow of each OD pair to various paths at once.

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See Also: Mode Choice Models; Network Modeling; Traffic Congestion; Traffic Flow; Travel Demand; Trip Distribution Models; Trip Generation Rates and Models.

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Rural Transportation Mobility

For many Americans, transportation—whether to work, medical appointments, shopping, or visiting friends and family—is given little to no special

consideration because more than 90 percent of Americans own at least one car, with 85 percent traveling by car to work each day. This is slowly changing as car-owning city dwellers forgo automobiles in favor of mass transit or car sharing. Nevertheless, privately owned automobiles continue to reign as king among transportation options.

Public transportation consists of a variety of modes, including buses, trolleys and light rail, subways, commuter trains, high-speed rail, streetcars, cable cars, van pool services, paratransit services for seniors and people with disabilities, ferries and water taxis, and monorails. In 2011, public transportation ridership was at its second-highest peak in 56 years, with 10.4 billion rides. Use of public transportation is not a new idea, but one that is gaining in popularity despite the stigma that public transit is the mode of transportation for the poor. This stigma is largely a result of a lack of clean and efficient public transit systems in the United States. Those with the financial means to avoid waiting in lines, sitting in crowded vehicles, and facing a perceived risk of assault often opt to transport themselves.

Approximately 15 percent of urban dwellers (nearly 8.3 million people) are classified as poor, as opposed to 7 percent of suburbanites. The prevalence of urban poverty is largely a result of the availability of public transportation: many poor people remain in urban centers because of the availability of public transit, which enables people who do not own a vehicle to work, shop, and access services. Their mobility out of the range of public transit routes is limited. But what of the rural poor, more than 8.5 million people, who live outside metropolitan areas?

Precarious Situation of the Rural Poor

Although poverty rates per square mile tend to be higher in urban areas due to higher population density, rural America contains more people in poverty. Many impoverished people in rural areas do not own automobiles, and the lack of public transportation severely limits their upward mobility. Nearly 70 percent of rural residents live in communities with little or no public transportation opportunities. Given the low population density, busing and rail become difficult if not impossible viable transportation options when people are far from would-be transportation hubs. Low personal-vehicle

ownership combined with low population density and disparate destination points for employment make it difficult to coordinate routes, and transportation becomes largely cost-prohibitive.

Rural transit has not only been found to be cost-effective, providing three times the benefit per cost, on average, but it can save federal and state governments money in the long run. When rural residents are able to access jobs, education, and child care, fewer residents are reliant upon social programs such as Temporary Assistance for Needy Families (TANF), Medicaid, and unemployment compensation. Families in rural areas are more often in need of social services and are more likely to be disabled or elderly than are their urban counterparts.

Nearly 90 percent of the counties in which poverty has persisted for several decades are in rural areas. Child poverty is particularly pronounced, and in 2006, 20 percent of rural residents had one or more disabilities, compared with 14 percent of urban residents. Despite the high level of need, rural families are less likely to use government support programs. Social service programs that are used struggle to serve all who reach out for help.

Access to Social Services

Despite their larger land mass, rural areas have a smaller tax base with which to work. This lower tax base, which means lower available funds for the public good, affects the availability of infrastructure, including social services and transportation to those services. Rural areas are also less likely than urban areas to benefit from philanthropic support to fund social services such as job training and mental health services. With families in rural areas often living many miles from the nearest town, limited transportation further distances the rural poor from government services and programs designed to help reduce poverty. Less than 10 percent of federal dollars allocated to public transportation goes to rural communities.

In reaction to the challenges of rural poverty and transportation, the U.S. government created a variety of grants to assist rural communities with transportation needs. Among these was the Job Access and Reverse Commute (JARC) program, administered by the U.S. Department of Transportation (DOT), with the purpose of transporting low-income residents and TANF recipients to jobs, training, school, and other social services, as well

as supplementing transportation services for health care and child support.

However, providing transportation service in rural (non-metro) areas can be cost-prohibitive because of the lack of population density and large distances to be covered. JARC authorized up to \$150 million per year for new or expanded transportation services while being funded through TAE-21 (the Transportation Equity Act for the 21st Century), which expired in 2003. Under SAFETEA-LU (Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users), JARC was authorized to spend \$165 million in 2009, only 20 percent of which was made available to rural communities. The funding for SAFETEA-LU expired June 30, 2012.

Rural Public Transit

Rural public transit, the equivalent of urban bus lines, provides transportation to the elderly, people with disabilities, and human services recipients. However, this form of public transportation is available to only approximately half of all rural counties nationwide. Of these, few are found in the most rural, isolated areas.

Established in 2004, the Federal Coordinating Council for Access and Mobility (CCAM) manages more than 60 programs that provide funds to transportation-challenged communities, with a priority of expanding the coordinated human services transportation infrastructure, also referred to as the United We Ride initiative.

Programs that support the purchase of vehicles for community transportation services include Community Development Block Grants (CDBG) from the U.S. Department of Housing and Urban Development (HUD) and Safe Transportation Funds from the Federal Highway Administration. Financial support of transportation facilities can be found through the U.S. Department of Agriculture's (USDA's) Intermediary Funding Program and the Federal Transit Administration's (FTA's) Non-urbanized Area Formula Transit Grants, alternately referred to as Section 5311 Grants. Typically ranging from one to 50 vehicles, 5311 transit systems are county based and are generally found in the more populated rural areas.

Tribal Transit

The vast majority of Native American and Alaska Native reservations are rural; only 10 tribes live in

metropolitan areas. Although poverty among rural Americans is generally higher than among urban or suburban dwellers, the poverty rate on reservations is approximately double (over 32 percent).

Since 2005 the FTA's 5311(c) Tribal Transit Program has distributed \$60 million to federally recognized tribes and Alaska Natives in rural areas, in addition to \$17 million of stimulus money in 2009 from the American Recovery and Reinvestment Act (ARRA), to plan, start, and enhance local transit services. Of the nation's 564 recognized tribes, 101 received transportation funding, a substantial increase from the 18 tribes that received transit funding from the FTA in 1999.

Despite the increase in funding, for future sustainability the National Congress of American Indians and the Intertribal Transportation Association's Joint Task Force on Tribal Transportation have urged Congress to further increase funding to at least \$15 million per year in the next federal highway bill.

Several factors indicate that an additional \$15 million per year would be insufficient to sustain the current growth of tribal transit. In 2010, over one-third of the applications to plan, build, and sustain transit were denied due to lack of funds. Inflation and fuel costs further increase start-up and operational costs for transit services. Budgets will also increase as the number of operators and riders increases.

Conclusion

Rural transportation benefits not only individuals but also the community as a whole. Access to transportation can bring new customers and tourists to rural towns, reduce congestion for those commuting to highly trafficked areas, and increase access to human services agencies and the services they provide.

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See Also: Accessibility and Mobility; Bus Systems, Rural; Job Access and Reverse Commuting Program; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Social Equity and Discrimination in Transportation; Transportation and the Disadvantaged; Transportation Equity Act for the Twenty-First Century.

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Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was the federal surface transportation reauthorization legislation signed into law in August 2005, after nearly two years of Congressional debate and 12 short-term extensions of SAFETEA-LU's predecessor, the Transportation Equity Act for the 21st Century (TEA-21).

SAFETEA-LU guaranteed \$244.1 billion funding for highways, highway safety, and public transportation for fiscal years 2005 to 2009, but analysts most often cite \$286.5 billion by including fiscal year 2004 funding (entirely covered by extension acts) to get a figure directly comparable to the six-year figures for the preceding transportation funding bills, the Intermodal Surface Transportation Efficiency Act (ISTEA) and TEA-21.

More evolutionary than revolutionary, SAFETEA-LU retained much of the core structure from ISTEA and TEA-21, but key changes included establishing a new core program for highway safety, updating several programs and planning processes, expanding

options for tolling and financing through public-private partnerships, and creating several programs to demonstrate new transportation technologies and study the future of transportation.

The Legislative and Political Process

As with TEA-21, the two major debates concerning SAFETEA-LU were the total size of federal funding and how to distribute that funding among the states. Donor states, mostly fast-growing southern states, wanted the TEA-21 guarantee of 90.5 percent return from funds contributed to the Highway Trust Fund (HTF) increased to 95 percent. Donee states generally had no problem with this as long as their funding was not cut. Many members of Congress wanted to increase the overall size of the bill substantially so that it would provide adequate funding for both donor and donee states. However, this was impractical without increasing the gas tax or adding general fund revenues, both measures President George W. Bush's administration was unwilling to take.

Bush's original SAFETEA 2003 bill, introduced in May 2003, concentrated on striking a balance between conservative pressure to avoid spending and public pressure to create jobs through infrastructure construction. This proposal eliminated most discretionary highway-grant programs to reduce the possibility that states and localities would match projects to available pots of federal

money rather than prioritize based on transportation needs. Bush's bill proposed spending \$247 billion over six years, and he threatened to veto any bill that went much higher.

Despite TEA-21's expiration in September 2003, the Senate Environment and Public Works Committee did not have a preliminary version of the bill ready for markup until November. In February 2004, the Senate passed its SAFETEA bill, allocating \$318 billion; in April, the House of Representatives passed a TEA-LU version for \$275 billion.

However, the conference committee hit gridlock trying to negotiate a compromise. By September, the House introduced another six-month TEA-21 extension, signaling that no new bill would emerge until after the 2004 election. After starting over in 2005, the final conference's work was to find a middle-ground number between the House's \$284 billion bill, favored by the White House, and the Senate's \$295 billion bill. The president removed his veto threat, mainly because changes to the tax treatment of ethanol fuel meant the HTF expected \$18.9 billion in additional revenue.

SAFETEA-LU's final negotiated price tag of \$286.5 billion made it look like Congress had given in to the president's demands much more than the actual spending expectations associated with it suggest. The final bill actually authorized \$295 billion in spending, but ordered \$8.5 billion of that rescinded for fiscal year 2009, a provision that at the time was thought likely to be reversed by a future Congress. The funds were spent in 2009.

The final total funding levels represented a 30 percent increase over TEA-21 levels, and the legislation's high levels of earmarking became an issue in the 2006 Congressional elections. In its final form, SAFETEA-LU included 6,371 earmarked demonstration projects, totaling \$14.8 billion over five years. This represented a threefold increase over TEA-21. Notably, the "Bridge to Nowhere," one such project in Alaska, became a symbolic term for such pet spending projects in the political battles that followed.

Core Programs

SAFETEA-LU kept the five major Federal Aid Highway Program categories associated with ISTEA and subsequently reauthorized through TEA-21. These were the National Highway System (NHS), Interstate Maintenance (IM) Program, the Surface

Transportation Program (STP), Congestion Mitigation and Air Quality (CMAQ), and Bridge Replacement and Rehabilitation (BRR). It added a new core program, the Highway Safety Improvement Program (HSIP); previously, 10 percent of the STP funds were earmarked for safety programs.

Funding for these six programs represented about 60 percent of the bill total, with NHS and STP being the largest. SAFETEA-LU retained the provisions in TEA-21 that allowed states to shift funds among the formula-driven highway programs, and between highway and transit projects. In addition, an Equity Bonus, introduced as a distributional mechanism for ensuring state returns on funds contributed to the HTF and growth from existing funding, joined the core provisions of the legislation.

The NHS, with \$30.5 billion funding for 2005 to 2009, represented funding for major highway, interstate, and principal arterial roads projects. It retained TEA-21's formula of distributing funds based on non-interstate lane miles, vehicle miles traveled, diesel fuel, and population. The IM program, designated exclusively for maintenance on interstate highways, received \$25.2 billion in funding.

The STP, authorizing \$32.5 billion in flexible funds that could be used for public transportation capital projects or highway infrastructure, continued the 10 percent set-aside for transportation enhancement projects but no longer required 10 percent be spent on safety improvements. The CMAQ program, receiving \$8.6 billion, designated funds for any transportation project that could help meet Clean Air Act requirements, and the BRR program's \$21.6 billion could be used for replacement or rehabilitation of bridges on public roads.

Safety Programs

The new HSIP designated \$5.1 billion from 2006 to 2009 for projects meant to reduce traffic fatalities and serious injuries on all public roads. After setting aside \$220 million for the Railroad-Highway Crossing program, funds were distributed according to the number of miles of federal aid highways, the vehicle miles traveled on them, and the number of fatalities occurring on them.

In addition to this new program, SAFETEA-LU introduced several other safety measures. The Safe Routes to School program was intended to fund both infrastructure and behavioral programs that encouraged primary school children to walk or

bicycle to school. The Work Zone Safety program combined a grant program for worker safety training, and new requirements for temporary traffic-control devices and high-visibility clothing in work zones. Other provisions addressed issues such as improving sign markings, and bicycle and pedestrian safety.

Distribution and Equity Bonus

SAFETEA-LU's Equity Bonus program replaced TEA-21's Minimum Guarantee program. It was designed to ensure each state received a minimum rate of return on its contributions to the Highway Account of the HTE. The rate was raised in steps from TEA-21's minimum 90.5 percent rate in 2005 and 2006, to 91.5 percent in 2007, and 92.5 percent in 2008 and 2009.

With \$40.9 billion set aside for it from 2005 to 2009, the Equity Bonus became the single biggest program in the bill. In addition to the minimum return ratio from the HTE, the Equity Bonus Program also guaranteed that states would receive a minimum increase relative to their TEA-21 funding levels.

Planning Process Changes

SAFETEA-LU's changes to the metropolitan and statewide transportation planning process included elements meant to streamline the complexities that slowed projects and to incorporate new planning requirements. Among streamlining measures was lowering the updating frequency from every two years to every four years for metropolitan areas' Transportation Improvement Plans (TIPs) and Statewide Transportation Improvement Plans (STIPs); a similar schedule modification was made for recertifications of metropolitan planning organizations.

The act also established provisions for cooperative planning for projects spanning state lines. Safety and security were split into separate items for consideration in both statewide and metropolitan processes, in alignment with the administration's focus on antiterrorism efforts.

The biggest changes were in the environmental review process for transportation projects. SAFETEA-LU created a new category of "participating agencies" to broaden the planning process to formally include more state, local, and tribal agencies. It also instituted a requirement that the U.S. Department of

Transportation (DOT) inform Congress of any environmental issue that cannot be resolved in 30 days and set a 180-day statute of limitations for lawsuits challenging federal agency approvals.

SAFETEA-LU also provided greater flexibility in allowing exemptions to Section 4(f), which prohibits transportation projects on publicly owned lands, recreation areas, wildlife and waterfowl refuges, or historic sites unless there is no feasible alternative and all possible mitigation is used. Under SAFETEA-LU, compliance with 4(f) could be achieved through the determination that a project would have no adverse effects on an area and state officials with jurisdiction over the property concur with this determination.

Further, SAFETEA-LU exempted the interstate system from being treated as a historic site under Section 4(f). In addition, a pilot program allowed five states (Alaska, Ohio, Oklahoma, Texas, and California) to assume all DOT environmental compliance responsibilities for highway projects under the National Environmental Policy Act (NEPA) and other environmental legislation.

Tolling

SAFETEA-LU created two new programs to offer states more flexibility to create pilot tolling programs to finance interstate highway construction and reconstruction, and continued tolling-related programs created under TEA-21. The new Interstate System Construction Toll Pilot Program allowed up to three demonstration projects nationwide to collect tolls to finance interstate highway construction.

The Express Lanes Demonstration Program was created to allow up to 15 demonstration projects using tolling to manage congestion. SAFETEA-LU also left unchanged the Interstate System Reconstruction and Rehabilitation Toll Pilot Program and the Value Pricing Pilot Program from TEA-21, allowing up to three tolling projects to fund interstate reconstruction that would otherwise be unaffordable, and allowing up to 15 tolling projects in nonattainment areas to reduce congestion and air pollution, respectively.

Public-Private Partnership Funding Options

SAFETEA-LU included several provisions to encourage private-sector involvement in transportation infrastructure projects. It expanded the

scope of existing Private Activity Bonds (PABs) by adding highway facilities and surface-freight facilities to the projects eligible for these bonds, which give the same tax breaks as bonds issued by government bodies. The act also expanded the State Infrastructure Bank (SIB) program, allowing all states to establish infrastructure revolving funds to make loans or enhance credit for transportation projects.

New Technologies and Studies

SAFETEA-LU authorized \$2.3 billion for research (which was less than under TEA-21), and the funds were directed entirely to designated projects and studies. The National Surface Transportation Policy and Revenue Study Commission studied the current conditions and future needs of the surface transportation system.

The Road User Fees Study authorized a long-term field test by the University of Iowa's Public Policy Center to assess the implementation of a vehicle-miles-traveled fee. Finally, the National Surface Transportation Infrastructure Financing Commission was formed to develop policy recommendations to help the HTF achieve sufficient revenues to meet future needs. The commission's report in February 2009 recommended a 10-cent-per-gallon increase in federal fuel tax, and a 15-cent-per-gallon increase in the diesel fuel tax to keep the HTF from near-term insolvency.

Among demonstration projects, the Highways for LIFE Pilot Program targeted fostering the use of new technologies and more efficient highway building. A maximum of 15 projects could receive this incentive funding per year, but, ideally, each state would receive at least one project by 2009. Through this program, the DOT would help states demonstrate and promote state-of-the-art technologies and performance standards for the highway construction process for improved safety, faster construction, and reduced construction-related traffic congestion.

Continuation

SAFETEA-LU was set to expire on September 30, 2009. Despite warnings from the National Transportation Infrastructure Commission that the HTF was nearing insolvency, the President Barack Obama administration recommended reauthorizing SAFETEA-LU for 18 months at its original expiration date in September 2009 to provide funding stability while Congress dealt with other complex

agenda items such as health care. Instead, Congress passed a total of 10 shorter-term extensions until the signing of the Moving Ahead for Progress in the 21st Century (MAP-21) Act in July 2012. Thus, SAFETEA-LU largely defined the shape of federal involvement in American transportation for seven and a half years, well beyond its original scope.

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See Also: Highway Trust Fund; Intermodal Surface Transportation Efficiency Act; National Environmental Policy Act; National Highway System Designation Act of 1995; Transportation Equity Act for the Twenty-First Century; Transportation Improvement Programs.

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Scenic Roads and Parkways

The evolution of the automobile has transformed roads from the science of strictly utilitarian transportation and economic necessities to the art of aesthetic assets. The federal government and local and state governments have cooperated in creating and maintaining scenic roads and parkways from the 1930s to the present.

Westchester County Parkway in New York and the Mount Vernon Memorial Highway in Virginia introduced an era of parkway and scenic road creation. In 1866 in New York City, Frederick Law Olmsted and Calvert Vaux had ideas about roads.

Originators of Brooklyn's Eastern Parkway in 1866, they felt that parkways were meant to restrict instead of encourage commerce. They believed parkways should be roads for pedestrians, bicyclists, equestrians, and carriages. Completed between 1870 and 1874, the Brooklyn Eastern Parkway was the nucleus of a plan for an interconnected park and parkway system in the New York area. The Olmsted and Vaux idea of bringing the countryside into the city influenced building major parks and parkways in cities across America.

Parkways Doubling as Freeways?

During the early 20th century, state and local governments expanded the Olmsted and Vaux definition of parkway to include landscaped limited-access highways designed for automobiles.

In its early days, the Vanderbilt Motor Parkway provided scenic routes without commercial vehicles or pedestrian traffic. Westchester County, New York, built four pioneering parkways between 1913 and 1930 and named them the Bronx River, Hutchinson River, Saw Mill River, and Cross County Parkways. The parkways were not built to establish the quickest and most direct route between origin and destination, but rather they were designed for moderate driving speeds so that motorists could enjoy the scenery.

Economic necessity, especially during the Great Depression, transformed the function of some parkways from beauty to business. The popularity of these parkways expanded the boundaries of New York City and led to its economic development. The building of the Arroyo Seco Parkway, the first part of the Southern California freeway system, during the Depression provided jobs for many people. When it opened in 1940, the Arroyo Seco Parkway reduced travel time between Los Angeles and Pasadena from 27 to 12 minutes. After functioning as the Pasadena Freeway and part of state Route 110 for decades, it was restored in 2010 and regained its original name.

In 1889, the U.S. Congress authorized a survey for the route of the Mount Vernon Memorial Parkway and passed enabling legislation for the parkway in 1928. In 1929, it renamed the project the George Washington Memorial Parkway. The parkway links George Washington's home at Mount Vernon, Virginia, with Washington, D.C., at the Arlington Memorial Bridge. Frederick Law Olmsted, Jr.,

Charles W. Moore II, and Gilmore D. Clarke helped create these first federal parkways. They borrowed some design features from the parkways in Westchester County, New York, and incorporated several ideas of their own and new technologies in road geometrics, bridges, pavement design, and construction that served as models for future highways and parkways. The National Park Service began administering the George Washington Memorial Parkway in 1933.

The New Deal Parkways

As part of the 1930s New Deal construction projects, the federal government built national parkways designed for recreational driving and earmarked to commemorate historic trails and routes. These parkways featured four lanes with lower speed limits. The National Park Service maintains these parkways, which include the Blue Ridge Parkway in the Appalachian Mountains of North Carolina and Virginia, the Skyline Drive in Virginia, and the Natchez Trace Parkway in Mississippi, Alabama, and Tennessee. The Colonial Parkway in eastern Virginia's Historic Triangle, the George Washington Memorial Parkway, and the Clara Barton Parkway that run along the Potomac River near Washington, D.C., were also built during the New Deal.

The Natchez Trace began as a buffalo and Native American trail and continued as a walking and riding trail for European traders and pioneers. The National Park Service Act of May 18, 1938, created the Natchez Trace Parkway as a National Park Service unit extending 444 miles from Natchez, Mississippi to Nashville, Tennessee, which preserves sections of the original trail. In 2009, the Natchez Trace Parkway had a total of about 5.9 million visitors enjoying scenic drives, hiking, biking, horseback riding, and camping. The sequestration provision of the Budget Control Act of 2011 required that the Natchez Trace Parkway budget be cut by 5 percent.

It took government agencies and private contractors over 52 years to complete the Blue Ridge Parkway, with the last stretch around Grandfather Mountain opening in 1987. The Blue Ridge Parkway grew into an economic necessity for the rural towns and villages along its route. In 2012, it drew an estimated 15.2 million recreational visitors to the area. The sequestration provision of the Budget Control Act of 2011 cut federal funding to national parks

and parkways and will adversely affect the tourist economy that is vital to the region.

Scenic Roads

With a few exceptions, state governments and the federal government did not formulate or adopt any organized plan of action for scenic roads in the first decades of the 20th century; instead, individual states and regions developed their own roads. Many were built sporadically for economic and practical reasons.

As early as 1913, Oregon authorized its first state highway commission to build a state highway system that included the Columbia River Highway in the Columbia Gorge that would preserve and compliment the area's beauty. Later highway commissions focused on protecting the environment as well as providing maximum recreation amenities for tourists. Oregon has designated 25 historic and scenic highway and bridge routes.

Vermont also instructed its State Highway Board to lay out a scenic route snaking through the central portion of the state from Massachusetts to the Canadian border; this later became Route 100. In the 1960s the Vermont state legislature addressed the problem of preserving scenic values along the state's highways.

States like Montana structured highways around their unique terrain and natural assets. In August 1872, Civil War General Philip Sheridan and 120 of his men crossed Montana's Beartooth Mountains returning from inspecting Yellowstone. Instead of detouring down the Clarks Fork River to Billings, General Sheridan followed the suggested route of an old hunter named Greer. When the Beartooth Highway opened in 1936, it followed General Sheridan's route over the pass.

When President Herbert Hoover signed the National Park Approaches Act in January 1931, the Red Lodge–Cooke City route of the Beartooth Road was the first park road to receive funding. The Beartooth Highway is a section of U.S. Highway 212 between Red Lodge, Montana, and Cooke City, Montana, that consists of a series of steep zigzags along the Montana–Wyoming border to 10,947-foot-high Beartooth Pass. It connects to the Chief Joseph Scenic Byway to Cooke City, forming the northeast gateway to Yellowstone National Park. Gateway communities scattered along the route depend on the highway for their economic

survival. The Beartooth highway officially opened on June 14, 1936.

The Great River Road

The Great River Road is an example of federal, state, and local governments cooperating over long distances to provide economic and aesthetic benefits to a large region of the country. Running along the Mississippi River from Minnesota to the Gulf of Mexico, the Great River Road is a 3,000-mile network of federal, state, and county roads that criss-cross the Mississippi River and encompass woodlands, river towns, farm lands, and villages.

The Mississippi River Parkway Commission (MRPC), comprised of members appointed by the governors of the 10 states along the Mississippi River, first proposed the idea of an extensive river road to federal officials in 1938. After World War II, Congress granted funds for a feasibility study for the road, and in 1954, it approved the road. Since then, the Great River Road has continually been developed using state funds and federal aid. In 1964, Congress expanded the northern boundary of the Great River Road from Lake Itasca in Minnesota to the Canadian border, permitting the provinces of Ontario and Manitoba to connect the 5,000-mile Trans-Canada Highway to the Great River Road.

National Scenic Road Programs

Despite impressive local and region scenic highways, a coordinated national scenic highway program did not appear until the 1960s. In 1962, President John F. Kennedy established the Recreation Advisory Council that included Secretary of the Interior Stewart Udall; Secretary of Agriculture Orville Freeman; Secretary of Defense Robert McNamara; Secretary of Commerce Luther Hodges; Secretary of Health, Education, and Welfare Anthony J. Celebrezze; and Administrator of Housing and Home Finance Agency Robert C. Weaver. The mission of the Recreation Advisory Council was to pinpoint recreational opportunities in America, and in its 1964 report the council recommended developing a national program of scenic roads and parkways.

The Recreation Advisory Council said that driving for pleasure was one of America's most popular outdoor recreational pursuits, and the number of families driving for pleasure would make an economic impact on tourism and sightseeing on scenic highways and parkways. The completed study, "A



The Linn Cove Viaduct around Grandfather Mountain on the Blue Ridge Parkway was the last stretch of the parkway to be completed, opening in 1987. It is a precast concrete segmental viaduct and the most complex structure of its type to be built in the United States at that time. It took 52 years to complete the entire Blue Ridge Parkway, which drew an estimated 15.2 million visitors in 2012.

Proposed Program for Scenic Roads and Parkways,” was published in June 1966; it recommended a scenic highway program and laid out its financing

On May 24–25, 1965, President Lyndon B. Johnson hosted a White House Conference on Natural Beauty for America to discuss environmental issues, including scenic roads. Congress passed the Highway Beautification Act of 1965, which provided for the scenic development and road beautification of the federal aid highway system.

Americans Outdoors and Scenic Roads

In 1985, President Ronald W. Reagan issued Executive Order 12503, establishing the Commission on Americans Outdoors. Chaired by Lamar Alexander, the commission published its findings in 1987, updating the Outdoor Recreation Resources Review Commission reports of the 1960s. The 1987 report included three recommendations for scenic

roads. The commission recommended that local and state governments create a network of scenic byways and act to protect them, and it suggested that Congress should establish an incentive program of matching grants from the Highway Trust Fund to encourage scenic byways development. It recommended private sector and government partnerships to provide information on scenic byways.

The Intermodal Surface Transportation Efficiency Act of 1991 established the National Scenic Byways Program, and the Transportation Equity Act for the 21st Century (TEA-21) reauthorized it in 1998. Under the program, the U.S. secretary of transportation recognizes certain roads as National Scenic Byways or All-American Roads based on archaeological, natural, cultural, historic, recreational, and scenic standards. There are 150 byways in 46 states. Arroyo Seco Parkway, Blue Ridge Parkway, Beartooth Scenic Byway, George

Washington Memorial Parkway, the Great River Road, and the Natchez Trace Parkway are all National Scenic Byways.

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See Also: Bureau of Public Roads; Highways, Rural and Low-Volume; Interstate Highway System; Recreational Travel; Tourism.

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School Bus Safety

Carrying over 25 million U.S. children daily, school buses represent a major source of transportation. With nearly 500,000 school buses traveling nearly 5 billion miles per year, the scope of America's school transportation program is both enormous and diverse.

Because of the long tradition of local control over public schools in the United States, a variety of local authorities administer school busing. This local control is tempered, however, by state and federal regulations designed to assure the safety of all riders. School bus safety involves consideration of factors involving construction, operation, regulation, and maintenance of the fleet and its drivers to assure the well-being of youthful riders. As with most considerations of this type, costs and benefits are carefully weighed so that school bus transportation balances safety and efficiency.

School buses remain the safest mode of transportation for children going between home and

school. Buses are also an effective means of reducing traffic on roads and near schools, which in turn protects pedestrians. While many school buses are owned and operated by school districts, others are controlled by third-party contractors who run them on behalf of schools and other organizations. Because of the importance accorded to children's well-being, school bus safety continues to be of concern to many facets of society.

Background

As public education became more common during the 19th century, transportation of children to schools became an issue of consideration. Children in rural districts often lived distances that were judged too far from their schoolhouse to be practical to walk. As early as the 1820s, horse-drawn buses transported children in England to school in a manner that was relatively safe, convenient, and efficient.

By the mid-1880s, Richmond, Indiana-based Wayne Works was manufacturing horse-drawn school carriages, which featured entry and egress through the rear of the vehicle, done in part so that children loading or unloading from the bus would not startle the horses. Once motorized school buses began being manufactured, this rear exit was maintained, as was perimeter bench seating within the vehicles that was attached to the walls. The first school buses were developed solely for local need, and varied greatly depending upon the place of manufacture.

While early motorized school buses featured roll-up canvas curtains as a means of covering windows in the passenger compartments, by the early 1920s Wayne Works began to offer glass windows in most of its vehicles. Gillig Bros., a San Francisco, California-based bus manufacturer, had introduced glass windows earlier, along with the "California top" roof, which featured a slightly curved metal top to the bus, with windows separated by regularly placed pillars that permitted each window to be opened using a latching mechanism. During the 1930s, Wayne Works and Crown Coach Corporation of Los Angeles, California, began offering all-steel-body school buses. Crown Coach's "Supercoach" was the highest capacity school bus of its era, seating 76 passengers.

During the 1930s, school buses began to be viewed as a distinct product, rather than an

adaptation of an existing product to be used to carry children. Based upon wagon manufacturing principles, school buses thus tended to be largely custom built, which decreased profitability for manufacturers, increased costs for school districts, and resulted in a hodgepodge of practices and customs. As standardization was seen as a benefit to profitability, decreased cost, and increased safety, certain features began to be found in all buses. To this end, innovations such as Gillig's steel-reinforced "California top" became the industry standard. As the automotive industry at large embraced all-metal-body construction of vehicles, school buses, which until this time had used a great deal of wood in their manufacture, also embraced this change.

In an effort to improve school bus safety, Professor Frank W. Cyr of Teachers College at Columbia University organized a national conference that met in New York City in 1939. Cyr, an expert in rural education, was keenly interested in school bus safety but realized that manufacturers also had concerns regarding the cost and construction of the vehicles. At this conference, Cyr was able to begin discussion that led to an agreed-upon set of industry-wide standards for school buses, a step that changed their design and production for the better.

Cyr, later referred to as the "father of the yellow school bus," was able to get transportation officials, school board members, bus body and chassis companies, paint manufacturers, and other interested parties to attend this conference. As a result of Cyr's efforts, a set of 44 standards for school bus construction were adopted by all manufacturers. These 44 standards led to consistent interior dimensions, seating configurations, and other features that permitted new consistency in industrial processes for body manufacturers. The adaptation of these standards led to decreased complexity in the manufacture of school buses, which also reduced the unit price for purchasers.

Ways of increasing school bus safety were also considered by conference attendees. After reflection, attendees determined that yellow was the easiest color to see at both dawn and dusk and, as a result, adopted what is now known as National School Bus Glossy Yellow as the standardized school bus color. Although this choice was never officially adopted by the federal government, it has become the de facto choice for school buses both

in the United States and globally. The success of the Teachers College conference led to continued efforts to improve the safety of school buses.

Evolving Safety Concerns

The decades immediately following World War II saw a baby boom that resulted in rapid growth in the school-aged population in the United States, especially in urban and suburban school districts. As a national shortage of building materials precluded immediate school construction to meet this need, school districts were forced to rely upon increased use of school buses instead.

For the first time, school buses began to evolve from what had primarily been a means of transporting rural children to school into a means of more fully utilizing the capacity of existing facilities. Conventional school buses, that is, those built on a truck chassis and sometimes referred to as Type C school buses, began to see increased competition from two variants. The first variant, transit-style school buses, offered increased capabilities such as greater seating capacity and better handling over conventional school buses. The second variant, small school buses, proved better able to handle routes that were inappropriate for conventional buses or that were intended for younger students or those with special needs.

By the 1950s, eight major school bus body manufacturers controlled production in the United States: Blue Bird Body Company; Carpenter Body Works; Crown Coach Corporation; Gillig Corporation; Superior Coach Company; Thomas Built Buses, Inc.; Wayne Corporation; and Ward Body Works. These manufacturers produced bodies for chassis made by three suppliers: Ford Motor Company, General Motors Corporation, and International Harvester Company.

The distinctive flat front-end design of the transit-style school bus, also known as Type D buses, makes them more similar to buses used in mass transit. As school enrollments boomed, transit-style school buses grew in popularity, especially on the West Coast, because this style had a larger capacity than conventional school buses. Maintenance and operating costs for transit-style buses were lower, as the increased capacity required a smaller fleet of buses, thus requiring fewer maintenance checks, drivers, and other associated costs. Small school buses, sometimes referred to as Type B buses,

proved useful for special school programs, such as those serving the gifted and talented or those associated with music and the arts. Small school buses are often equipped with special devices to assist people with disabilities, such as automated lifts.

As the federal government became more concerned with vehicle safety overall, this interest extended to school buses as well. Beginning in 1977, the Federal Motor Vehicle Safety Standards for School Buses were initiated. These have played a role in changing the design and construction of school buses, alterations made in an effort to make these vehicles safer and more reliable for the children they serve. In all, over 35 federal motor vehicle safety standards apply to school buses, with several written specifically for those vehicles. As U.S. congressional concern has ebbed and flowed regarding school bus safety, these standards have been revised, rewritten, and expanded.

Safety Modifications

Certain safety modifications that have been mandated for school buses have affected all motor vehicles and have been relatively simple to implement. Others have been specifically designed for school bus manufacturers and have proven very costly. Still other proposals have occasionally generated popular support but have proven difficult or impossible to achieve.

Beginning in the 1970s, for example, school buses, and indeed all motor vehicles, were required to have rearview mirrors installed in an effort to reduce the number of injuries that occur when a driver does not possess a clear and unobstructed view to the rear. Similarly, electronic stability control systems have been mandated on all multipurpose vehicles weighing in excess of 10,000 pounds, including school buses, in an effort to reduce the risk of roll-over crashes and the potential deaths or serious injuries they may cause. Because these alterations were required on all vehicles, an economy of scale exists that makes the cost of such modifications to the design process reasonable and affordable.

Federal standards have also required that all body panel joints that comprise school bus bodies be strengthened, reducing the chance of structural collapse of school bus bodies during crashes, thereby reducing deaths and injuries resulting from these crashes. Additionally, all school buses were required to have higher, well-padded seats installed,

which provided increased protection to passengers in the event of a crash. Although this standard applies only to school buses, the universality of its nature levels the competitive playing field insofar that every bus manufacturer and operator must bear the same expense.

For decades, certain groups have advocated for safety belts on school buses. Despite demands for seat belts on school buses from some quarters, in 1977 the federal government instead decided to strengthen structural requirements for the vehicles in conjunction with better passive restraint requirements. These changes exempted school buses that weigh in excess of 10,000 pounds from having to install seat belts.

Opponents of seat belts on school buses assert that their superior construction and safety features make them safer than automobiles, making the passenger restraint devices found on the smaller vehicles unnecessary. Data from the National Highway Traffic Safety Administration indicates that a child is 50 times more likely to be killed on the way to school if traveling in an automobile driven by themselves or their friends than if they take a school bus.

Several states now require seat belts on certain school buses. These states include California, Florida, Louisiana, New Jersey, New York, and Texas. Beginning in 2011, the federal government has begun requiring the passenger restraints on van-based (Type A) school buses. Seat belts potentially reduce the number of children that can be served by a single school bus, especially in states such as New Jersey where every child is required by state law to wear a seat belt (in other jurisdictions, this is the choice of the school district) or in states such as California that require three-point (shoulder) seat restraints. Either of these options could require the purchase of more vehicles, as the existing fleets would be unable to serve the same number of children while also complying with the new seat belt requirements.

Traffic Laws and Safety Devices

Since the 1939 Teachers College conference on school bus safety, most school buses have been painted the color known as National School Bus Glossy Yellow. Once school buses became instantly recognizable with their distinctive color scheme, it became easier for states to promulgate, and enforce, traffic laws related to school buses.

For example, by the mid-1940s, the majority of states had passed traffic laws that required other vehicles to stop whenever a school bus was loading or unloading children.

This prohibition was popular because many children do not fully comprehend the hazards and potential consequences presented by traffic, and the size of the large yellow bus often limits the sight lines for both children and adults. In all 50 states and the District of Columbia, other traffic must stop when a school bus is loading or unloading, although the distance kept by other vehicles varies depending upon jurisdiction.

As the understanding of the potential threats to children have increased, and as technology has advanced, a variety of safety devices have also been installed on school buses to better protect passengers. Warning lights first began being used on school buses in 1946 in Virginia. At that time, Virginia buses used a series of four red lights, two each to the front and rear of the bus, to indicate that boarding was taking place. Automated either by a mechanical switch attached to the door control or via a pressure-sensitive switch connected to a paddle-operated stop sign located to the left of the driver's seat, the warning lights alternated to warn other vehicles of the possible presence of young pedestrians.

As time has evolved, many states now have increased the number of warning lights needed to eight, four in the front and four in the back. While some states require the use of a combination of both amber and red lights, other jurisdictions such as Wisconsin mandate that all lights used be red.

Beginning in the early 1950s, some states began permitting the use of a mechanical stop sign that would swing out from the left side of a bus when a stop was in progress. The stop sign was intended to warn passing traffic that a stop was in progress. Initially it was a rectangle with the word "Stop" printed on it, but the U.S. National Highway Traffic Safety Administration now has established a standard for all such stop arms. The mechanical sign now must be a double-faced regulation red stop sign, octagonal in shape, and at least 17.7 inches across, using a white border and uppercase letters. The mechanical sign must be equipped with flashing red lights, use reflective paint, or both. Some mechanical signs use light-emitting diodes (LEDs) to further focus the attention of drivers of other vehicles.

All school buses have an emergency exit door located in the rear of the bus, a feature that dates to the horse-drawn wagons that predate modern motorized vehicles. These rear emergency exits, which are window exits in the event of a rear-engine bus, are augmented by additional escape modes. These may include roof hatches, window exits, or side emergency exit doors, or a combination thereof. These exits are activated by a release latch, which simultaneously activates an alarm at the front of the bus. The number of exits required on a given bus varies, depending upon its capacity and the governing jurisdiction's requirements.

Federal motor vehicle safety standards also require the use on school buses of retroreflective conspicuity tape along the sides and rear of buses to indicate their height, width, and length. The use of such retroreflective conspicuity tape assists other drivers, making it easier for them to see the size of the bus in darkness or inclement weather—the combination of the tape and the drivers' own headlights allows them to more correctly perceive the vehicle's size and position. All emergency exits must also be so marked, so that first responders and other emergency personnel can quickly identify these in the darkness.

Additional Safety Standards

Individual jurisdictions have used advancing technology to provide additional features that improve the safety of children on school buses. For example, Illinois and many school districts in other states require strobe lights to be used on the roofs of buses. As the cost of video technology has decreased, many school districts and contractors now require video cameras to be installed inside school buses. Although initially installed primarily to monitor and record passengers' behavior, video technology has also been useful in detecting inappropriate or illegal behavior on the part of school bus drivers or other personnel.

Despite all of these safety efforts, nearly 66 percent of students killed outside a school bus are killed not by another vehicle but by the bus that they regularly ride. In an effort to improve safety, comprehensive mirror systems have been developed in an effort to reduce bus drivers' blind zones. Windshields on Type C and Type D buses have been enlarged in an effort to remove obstacles from a driver's line of sight.

As video technology advances, this has greatly assisted in improving bus drivers' awareness of children around their vehicles. Increased emphasis has also been placed upon improved education that assists children in recognizing dangerous situations and utilizing the appropriate level of care to avoid tragic injuries or death.

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See Also: Accessibility and Mobility; Americans with Disabilities Act of 1990; Benefit–Cost Analysis of Transportation; Bus Capacity; Bus Design; Buses; Passenger Van Safety; School Buses; School Transportation.

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kindergarten students may be driven to school by their parents or a car pool, especially in districts where the kindergarten is not integrated with the elementary school.) The major exceptions are urban school districts where children take ordinary public transportation or live close enough to walk. In exurban and rural districts, walking may be permitted (or required) of students who live within a given radius of their school, and driving may be required of students who live outside a second radius, a factor that has to be considered when building new housing developments or residential streets.

Originally, students were expected to walk to school, and buses were introduced in rural areas for the sake of students on far-flung farms and ranches. The earliest buses were horse-drawn carriages called "school trucks," and were equipped with a rear door for entry so that boarding students would not upset the horses (intentionally or otherwise). The first buses with engines retained this rear door, which today is used as an emergency exit. The modern school bus originates in the 1930s and 1940s, when "school bus yellow" was introduced as a standardized bus color. Believed to be the easiest color to see in dark or winter twilight conditions, school bus yellow is officially called National School Bus Glossy Yellow in the United States. Though not mandated federally, and a small share of school districts use other colors, most districts and manufacturers have used National School Bus Glossy Yellow for decades.

Around the same time that school bus yellow was introduced, most of the country adopted—often as part of a new wave of traffic laws, reflecting the increasing role driving played in American life—new laws requiring traffic to stop while children are boarding or disembarking from a school bus. Many also require drivers to maintain a greater than normal distance from school buses in front of them, for a number of reasons: it keeps the car out of the bus driver's blind zones, it reduces the odds of a rear-end collision, and it provides additional braking time in the unlikely event that a child manages to open the rear emergency exit.

The three most common types of school buses are deployed for varying purposes. The conventional school bus design, Type C, uses a truck chassis, resembling an elongated truck cab with modified doors and windows. This has remained the most popular school bus type in the country for

School Buses

In the United States, school buses are the default form of transportation for public school students in most districts. (At least for grades one through 12; because of their young age, in many places

default school transportation. In some districts, the more recent transit-style or Type D of school bus, which has a flat front like a motorcoach or public transit bus, has become more popular, in particular on the West Coast where the first popular model thereof was developed, in the 1950s. Type D buses have a larger passenger capacity than the conventional bus and so are more likely to be deployed in densely populated districts or those with rapidly expanding populations. Smaller school buses based on the chassis of a van (Type A buses) or step van (Type B buses, rarely manufactured today but still in use in some fleets) are often used for specialized low-ridership purposes like the transportation of disabled students, magnet school routes, or special occasion travel such as field trips.

Safety Standards

The Federal Motor Vehicle Safety Standards for School Buses were established in 1977, and along with the standards established by other laws, a total of 37 federal motor vehicle safety standards apply to school buses (though not all 37 are relevant to every model of school bus). For instance, in 1991 the extendable stop arm was mandated as a pedestrian safety device in order to notify approaching traffic of their requirement to stop until schoolchildren (or other disembarking pedestrians) have left the street. It has been amended several times, most recently in 1998, when strobe lights and LED lighting was permitted. Other standards mandate electronic stability control, standards for mirror placement and design, crash protection, emergency exits, seat belt assemblies, durable and well-padded seats, reinforced body panel joints in order to reduce fatalities in the event of structural collapse, and rollover protection. According to a 2002 report by the National Highway Traffic Safety Administration, students are significantly safer in schoolbuses than driving to school by car—eight times safer.

Fuel

Recent debates about school bus policy have often centered around fuel consumption, both for economic reasons—oil price shocks wreaked havoc on the budgets of school districts in the late 2000s, for instance, as they had done several times in the 1970s and 1990s—and for environmental reasons. Environmental concerns over the exhaust produced by school buses are not limited to the effects thereof



Yellow school buses in a parking lot near Coney Island in Brooklyn, New York, in 2006. The rear door exits seen here evolved from the rear exits of early horse-drawn "school trucks."

on climate change; many parents and others also worry about the health effects of the exhaust on students waiting near idling buses to leave school.

Many fleets adopted diesel engines in the 1980s, during a resurgence in the popularity of diesel fuel as an alternative to conventional gasoline. They have since become the predominant engine type, making possible conversion of school bus fleets to biodiesel consumption. While explored in many school districts and pilot projects, biodiesel conversion has been popular primarily in affluent districts and districts awarded federal or private-sector grants. While school transportation was largely neglected in the first part of the federal economic stimulus package of 2009, later programs established with stimulus money did deal with converting school bus engines to biodiesel or compressed natural gas.

GPS

As GPS technology has become cheaper, many manufacturers have offered it as an optional feature in their buses. GPS is used not only for safety purposes but for fleet management, allowing a central

authority to keep track of where on the route each bus is, what delays are being experienced, and other factors. Though there are safety concerns about revealing location information in real-time, some districts allow parents to access it (in order to be sure they meet their child at the bus stop, for instance) or to receive proximity alerts on their phones. In the unfortunate event of a missing or abducted child, these systems also provide investigators with more granular information about the child's last known location.

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See Also: Bus Capacity; Bus Design; Bus Engines; Bus Routes; Buses; School Bus Safety; School Transportation; Student Transport.

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School Transportation

School transportation is the transportation of students to and from school, especially the daily transportation of minor children. About 25 million American children depend on the school bus as their primary means of school transportation, though there are transportation issues faced by boarding schools (for which transportation is less than daily) and universities, where students reside on campus and need transportation across campus or from campus to various local destinations.

Such busing is nearly always zero-fare, and in many cases, bus drivers are familiar with the students on their route and no ID or pass is required.

School transportation includes bus transportation, which itself includes the use by schools of an existing bus transit service, as well as the maintenance and dispatch of a dedicated school bus fleet. Students also may arrive by foot or bicycle, be driven to school by car by parents or others, or drive themselves once they reach driving age.

Transportation policy needs to address the basic need of getting students to school, as well as how the school will handle the impact of unusual events on transportation, such as delayed openings or early closings due to weather; the transportation of students from the school to other destinations, such as on field trips; the transportation of students who remain on campus for after-school activities or because of after-school detention hours; the transportation of student athletes (and spectators) to away games; and the transportation of students to sanctioned events for student groups, such as debates or academic competitions.

A transportation policy must also encompass the handling of exceptions to whatever the transportation norm is for the school. In a school in which students are picked up at home and transported to school by bus, for instance, policy would address the handling of students who want to walk, bicycle, or drive to and from school instead; students who want to take the bus to a friend's home after school; the handling of traffic caused by parents picking up or dropping off children in lieu of using the bus; and the various legal and liability issues brought up by transportation policy and the responsibilities of the school to the minors in its care.

In North America, it is common for public schools to use fleets of dedicated school buses painted National School Bus Glossy Yellow, a paint color developed in 1939 specifically for this purpose. The color is designed to be easily noticed by drivers in their peripheral vision and rearview mirrors, and to stand out in traffic. It also makes the bus easily identifiable by young children. The visibility of school buses is important not only for safety purposes—because the bus makes frequent stops, it is important for drivers to be aware of its presence—but also because a number of traffic laws privilege the school bus and require certain behaviors of drivers.

In almost every state, for instance, drivers (regardless of lane or direction of traffic) must stop when a school bus is loading or unloading passengers. This shifts the burden of safety from the children to the drivers, essentially stopping traffic until children are either safely on the bus or have moved away from the street. Often a school bus will be equipped with a foldout double-faced stop sign (called a stop signal arm) reminding drivers of this, although the law is binding regardless. Other warning devices may include flashing lights.

Sometimes, depending on policy or the driver's own practice, the bus will remain stopped until disembarking children have left the bus stop. In particular, the bus often remains in place—forcing traffic to remain halted—until any children who need to do so have crossed the street. The usual exception to the school bus traffic priority law is on divided highways, where only traffic headed in the same direction as the bus is required to stop (New York is one of the few states without this exception). Because violations are common but difficult to prove, the beginning of a new school semester is often accompanied with increased traffic police presence in order to crack down on violators.

Transportation policy considers not only safety practices and the manner of bringing children to school but also the consequences of transportation policy choices in other spheres. School bus pollution is considerable, for instance, though it is much less than the same pollution that would be contributed by individual cars carrying the same number of students to school (even if that number were reduced through carpooling).

Nevertheless, school buses tend to remain in use longer than the average passenger car and are designed for durability and longevity so that their cost can be amortized by the school board or transit agency over a long period of time. For this reason, many of the school buses in use at any given time are considerably less fuel efficient and bigger contributors to greenhouse gas emissions than equivalent new models would be. There are a number of federal, state, local, and private-sector initiatives aimed at encouraging schools to convert their fleets to cleaner buses, either by phasing out older buses or by converting gasoline- or diesel-powered buses to those using biofuel, methanol, compressed natural gas, electric hybrids, or other alternatives.

Campaigns against childhood obesity and in favor of childhood physical fitness have often advocated active transportation, meaning transportation by foot or bicycle. Access to walking or bicycling has been frequently correlated to better fitness levels and higher daily levels of physical activity, and active transportation programs can increase that access. This is an area, though, where transportation policy is limited by other policies enacted by other entities.

The ability of a child to walk to school, or to walk safely in his or her neighborhood at all (or that of the school), is determined by the built environment: the man-made surroundings of the neighborhood, including the presence and upkeep of sidewalks, public parks, footpaths, and crosswalks, and the amount of traffic that must be negotiated. Childhood obesity is more prevalent in neighborhoods with poor walkability because of these factors, but those neighborhood factors also make walking to school a less practical solution.

Federal grant money is available to states that develop Safe Routes to School programs, which are designed to encourage children to walk or bicycle to school by developing and implementing projects to increase walkability and bicycle usage. In order to reduce concerns about unescorted minors walking to school, the “walking bus” and “bicycle train” concepts are sometimes used, each of them consisting of a group of walking or bicycling children (increasing in size as they follow a route taking them past other students' homes) led by adult chaperones.

Desegregation

School transportation also includes busing for the purposes of desegregation, a practice especially associated with the 1970s and 1980s, and somewhat less common now. Before the 1954 Supreme Court decision in *Brown v. Board of Education* made racial segregation unconstitutional, there were essentially two forms of segregation in the United States: segregation by explicit policy (de jure segregation), in which separate schools were maintained for students according to race, and de facto segregation, in which schools were primarily or exclusively white or black because of school district zoning and factors other than explicit policy.

In some cases, de facto segregation was created in order to bypass the court's ban on de jure

segregation. A school district could be created consisting of most of a city's predominantly black neighborhoods, for instance, essentially creating an all-black school without need for an explicit policy. In other cases, especially in the north, de facto segregation existed because of long-standing traditions of settlement and the tendency of neighborhoods to be racially homogenous (a tendency that in various eras had been reinforced by federal and state housing policies and the mortgage-lending policies of banks, as well as by the real estate industry).

However, de facto segregation was not spared for long, and in a lesser-known 1971 case, the Supreme Court recognized the federal government's power to use busing for desegregation. In such a practice, students are bused to schools to which the local district division would not otherwise assign them, in order to break conditions of de facto segregation.

Desegregation busing began in Boston when Massachusetts passed the first-in-the-nation Racial Imbalance Act, which tied state education funds to desegregation. The busing plan implemented in the Boston area was fiercely opposed in the Irish American neighborhoods of Charlestown, Dorchester, South Boston, and Roslindale and the Italian American North End. As implemented by Judge Arthur Garrity, Jr., Boston busing was not a matter of shifting a small number of students; Garrity ordered large numbers of students to be redistricted, in one case busing the entire junior class from a mostly white school to the predominantly black Roxbury High School. Protests were fierce, and many of Garrity's choices were questioned even by busing advocates. Boston busing eventually ended in 1988, at which point the Boston school district had shrunk to nearly half its previous size.

Boston had experienced the same phenomenon that was at work in much of the rest of the country and that was responsible for the decline of busing: white flight, as middle-class and lower-middle-class white families left the city centers for the suburbs. The schools they left behind became less predominantly white as a side effect, as nonwhite families filled in the empty spaces. In other cases, wealthy families increasingly sent their children to private schools where conditions of de facto segregation were common, but beyond the reach of federal policy.

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See Also: Bus Routes; Buses; Commuting; School Bus Safety; School Buses.

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Section 504 Regulations on Accessibility

The Rehabilitation Act of 1973 marked the first substantive legislation in the United States designed to ensure equal treatment and services for individuals with physical or cognitive disabilities. Its doctrine expressly prohibits discrimination on the basis of disability in federal government and federal contractor employment practices, in programs administered by federal agencies, and in any program receiving federal financial assistance. Public transportation operations fall under these categories, making them subject to compliance with the act's regulations.

The underlying principle of the act is that mass transit should not hamper the ability of people with disabilities to participate fully in society and actively engage in employment, educational, and cultural opportunities. As such, U.S. public transportation systems are required by law to provide accommodation that enables access to public transit by

individuals with disabilities. The transition toward greater access following the Rehabilitation Act in the 1970s was initially a rocky one, requiring additional regulations to clarify definitions and responsibilities. Over time, however, the broad social and economic benefits from greater access to public transportation for all individuals have become more evident.

Components and Definitions

When passed by Congress in 1973, the first three titles of the Rehabilitation Act provided for a wide range of vocational rehabilitation services, including research and training, and outlined federal responsibilities. The fourth title established the National Council on the Handicapped, which became an independent federal agency in 1984 known as the National Council on Disability, responsible for advising the president, Congress, and other U.S. federal agencies regarding programs, practices, and policies affecting individuals with disabilities.

The act's fifth title addressed miscellaneous provisions and included four key segments. Section 501 prohibited discrimination against the disabled by the federal government. Section 502 targeted reduction of mobility barriers for disabled individuals in public places. Section 503 prevented discrimination against the disabled by government contractors. Section 504 barred federally funded programs from discriminating against individuals with disabilities. The final two titles of the Rehabilitation Act, Titles 6 and 7, dealt with employment opportunities and independent-living services for the disabled.

The original definition of a disabled person in the Rehabilitation Act of 1973 included only individuals who had a physical or mental impairment resulting in a significant hindrance to employment, and who could reasonably be expected to gain employability advantage as a result of vocational rehabilitation services as provisioned under the first three titles of the act. However, in 1974, Congress amended the Rehabilitation Act under Section 504 to expand the definition of a disabled individual beyond the specific employment scope.

The broader definition identified a disabled person as someone who is regarded as having a physical or mental impairment that significantly limits one or more major life activities, which may include anything from seeing or walking to learning or breathing. Essentially, any limitation that debilitates

one's independent living or inclusion in U.S. society could be considered a disability under the expanded definition. The amendment was intended to ensure that federally funded programs are operated without discrimination against any disabled individual, not just those whose disability affects their employment status or experience.

Each federal agency has its own set of Section 504 regulations that apply to its own programs. Agencies that provide federal financial assistance to others also have Section 504 regulations pertaining to the entities that receive the federal aid. Requirements common to both categories of the regulations include providing reasonable accommodation for individuals with disabilities, ensuring program accessibility to those individuals, delivering effective communication to individuals who have hearing or vision impairments, and providing accessible facilities in new construction or modifications to existing sites and equipment. Each agency is responsible for enforcing its own regulations.

Impact on Transportation

As a result of Section 504 of the Rehabilitation Act of 1973, the Federal Transit Administration (FTA), which was then known as the Urban Mass Transportation Administration, issued regulations that required special efforts to be made in the planning of public mass transportation facilities to accommodate the needs of elderly and disabled individuals. The regulations also required that all new transit vehicles and facilities be accessible to the disabled.

More stringent regulations were published in 1979, mandating that all existing bus and rail systems that received federal funding be retrofitted to become fully accessible to disabled persons within a three- to 30-year time span, depending on the size and type of transit operation. For example, the 1979 regulations required that 50 percent of the buses in fixed-route service be modified to ensure accessibility and safety for wheelchair users within the first three years, while railcar retrofits, including bathrooms and sleeping compartments on long-haul trains, had up to five years to comply. Rail facility accommodations were given a 30-year window. Transit operations had to show steady progress toward achieving accessibility in order to be considered compliant.

Additional regulations adopted in 1986 established six service criteria that applied to urban mass

transit systems—with some exceptions applied to existing rail systems—for individuals with disabilities. First, anyone who is physically unable to use the public bus system must be treated as eligible for special accommodation. Second, the accommodating service must operate during the same days and hours as the general service. Third, the specialized service must operate in the same geographic area as the ones serving the general public. Fourth, passenger fares for carriage on both the specialized and public services must be comparable. Fifth, the specialized service must be provided within 24 hours of a specific request. Finally, restrictions or precedents for specialized service may not be imposed based on the reason for the travel itself. In other words, the purpose of the travel cannot serve as a basis for limitation or prioritization of service.

Transit authorities were allotted a one-year planning stage in which they were required to involve the disabled community and other interested parties from the public. They had up to six years after planning to phase in the new services and, again, were required to include disabled participants throughout the implementation process. To prevent undue financial burden on transit authorities, the regulations capped the amount of money transportation agencies were required to spend on the provision of specialized services to 3 percent of their annual operating expenditure. This limit was lifted in 1990 when the Americans with Disabilities Act (ADA) was adopted.

Rulemaking for the Section 504 regulations was one of the most complex and drawn-out processes in U.S. Department of Transportation history. It required balancing the concerns of the disabled community that needed sufficient access to public transportation with the concerns of transit authorities and local governments that wanted to avoid costly and time-intensive accommodation requirements.

The balancing act stimulated a fierce debate between those who felt that disabled individuals should have the right to be mainstreamed into society and those who believed that there were more cost-effective ways of providing transportation for that group using paratransit services. Paratransit is essentially on-demand, door-to-door services for individuals or small groups who are physically unable to use standard public transit systems.

The latter contention was based on the widespread opinion among transit professionals that

there were not enough new transit passengers to validate the expense of providing mainstream transit access for individuals with disabilities. However, the reality was that demand for paratransit services far exceeded the expectations of transit agencies, with eligible passengers using the specialized services more frequently and for more purposes than had been estimated by transit planners. Transportation agencies have been trying to manage regulatory requirements and higher demand for specialized services ever since, while contending with generally flat funding, diminished utilization, and declining service quality in conventional transit services.

Broad Economic Benefits

To promote compliance with Section 504 of the Rehabilitation Act and the subsequent ADA, the FTA points transit authorities to the economic benefits of providing transit access for individuals with disabilities. For example, there are direct economic benefits to the individual using the service and to those in his or her household because the individual is able to participate in employment and educational opportunities. Accessible transit for the disabled also imparts incremental benefits to other transit passengers who are not counted as having disabilities in that it strengthens and diversifies the workforce, reducing the burden on those who would otherwise carry the full fiscal load.

Additional economic benefits can be found in the costs saved by public and private businesses when their clients and customers have ready access to them via specialized transit services. Moreover, the increased participation in society among formerly isolated individuals and the regular use of specialized transit services produce overflow benefits to the general taxpayer by way of producing a more efficient economy.

Consider a dialysis patient, for example. When a transit provider offers mobility services that enable a dialysis patient to receive needed treatment, it eliminates the use of costly ambulance shuttle services that would otherwise be used in some cases. For patients whose medical travel is paid by publicly funded medical assistance programs, the savings to both health and human services agencies and taxpayers is potentially significant.

The U.S. Department of Transportation routinely measures the economic value of transit accessibility based on perceived benefits not only

for passengers with disabilities but also for local taxpayers and the public at large. The findings have suggested that the benefits from accessible transit services are substantial and far exceed the start-up and maintenance costs of most specialized transit services. More than favorable economics, however, accessible transit services provide disabled individuals with greater independence and improved quality of life.

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See Also: Accessibility and Mobility; Americans with Disabilities Act of 1990; Bus Design; Demand-Responsive Transit; Evaluation Studies of; Elderly and Disabled Travelers; Handicapped Access; Jitneys; Shared Taxis; Social Equity and Discrimination in Transportation.

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Security, Transportation

The contemporary international scene is characterized by ever-increasing mobility of people, capital, and goods. Such mobility depends on an effective transportation system, one that is secure from disruption by international terrorism. Attempting to ensure that people can continue to avail themselves of various mobility options and that trade can continue to flow smoothly and economically has become an international priority.

Terrorist attacks have inflicted serious damage to transportation facilities in many countries. Airports and airlines have been attacked in Israel, Spain, India, South Korea, and Scotland, as have mass transit facilities in Spain, the United Kingdom, and Japan, often with devastating consequences in terms of human lives and economics.

The issue of how to improve security in transportation is greatly complicated by the growing economic and personal interconnectedness that characterizes the modern world, as technological changes in transportation and communication lead to ever greater movements of goods and people. Protecting an infrastructure that handles such an enormous volume of freight and passengers is clearly a gigantic task.

Transportation targets appeal to terrorists for many reasons. First, transportation is a major sector in any economy and a significant contributor to national growth. The global freight system, which is vulnerable at many points, is of particular concern because of the national and international consequences of a successful attack. International trade would be halted and economic growth throughout the globe would slow, imposing a heavy burden on all states, especially upon those least able to bear it.

Second, terrorists now seek to inflict as many casualties as possible. Transportation nodes—stations, subways, and airports—are therefore appealing targets. The March 2004 attacks on the Madrid train stations, where over 170 people were killed and many more injured, and the July 2005 attacks on London's underground system, which killed 56 people (including the four suicide bombers) and injured about 700, provide vivid and tragic proof of the appeal of these targets.

Third, transportation facilities are often national and international icons, and the demolition of a famous bridge or a well-known tunnel would possess great symbolic significance.

Effective transportation security presents a secondary positive aspect as an essential counter-terrorism tool. Terrorists have to travel to their targets with their weapons or to a place where they can obtain them. A secure transportation system can obviously limit the mobility of terrorists, an issue of growing concern to law enforcement agencies everywhere.

Effective transportation security can also increase the security of vehicles that can be, and sometimes

have been, used as weapons. The tragedy of September 11, 2001, in New York and Washington, D.C., was the result of airplanes transformed into missiles and fired into buildings. More common are truck bombs, which have been launched against intermodal terminals, bridges, tunnels, vessels in port, trains, and buses.

Terrorists are also exploring the potential of other weapons, including radioactive materials. The acquisition of 110 pounds (50 kilograms) of highly enriched uranium (HEU) would permit terrorists to assemble a nuclear weapon, albeit an inefficient one. However, building a bomb is a difficult task, even with the necessary materials and the technical know-how. More likely is an attack using a radiological dispersal device (RDD) that explodes and disseminates radioactive materials in a transportation facility or disperses such materials in powdered form, perhaps from a plane.

Even more likely are chemical and biological attacks, because terrorists can easily acquire numerous agents that cause diseases such as the plague, botulism, and smallpox. The deployment of a few grams of these microbes would cause death and create panic. Many other virulent toxins can be identified, some of which (such as sarin gas and anthrax) have actually been used. Each of these substances poses unique challenges that require particular countermeasures and responses, which also depend on the nature of contexts and resources.

Cyberattacks, which are commonplace, also pose a significant threat. These can take many forms. A specific database of a transportation owner/operator could be attacked in order to gain information, or an attacker could seek out a weakly defended pathway for access to a network in order to shut down service or to introduce harmful instructions. Attacks could be launched against highway traffic, train control centers and air traffic control systems, ports, power and telecommunications systems, and railroad signals. A successful attack that led to the derailment of a train loaded with chlorine in an urban area, for example, would have devastating consequences.

Globalization and Intermodalism

Since attacks against transportation systems can take many forms, safeguarding transportation systems is a challenging task. But two macro developments further compound the challenge.

Technological developments, particularly in the fields of transportation and communications, have made the world a smaller place. As distance and time have shrunk, an ever-growing flow of people and goods across national frontiers further accelerates the process of economic and financial integration. Today, companies produce in many countries, ship components from one subsidiary to another, distribute finished goods to markets in many countries, and use the transportation network as a warehousing system.

Safeguarding this system is no easy matter. First, sheer size creates difficulties. Container freight has grown exponentially in the few decades since its introduction. Today, about 90 percent of the world's cargo movements involve containers, and millions arrive at major seaports each year.

Second, the economic and technological integration that has been achieved has not been matched by an equal degree of political coordination and cooperation. There is a growing discrepancy between traditional borders and economic boundaries, which continue to expand outward as a result of various international trade agreements. Therefore, new questions have emerged to complicate the already complex and difficult issue of border security. Does the United States, for example, maintain inspection and verification rights at its own borders, or does it delegate them to the Mexican and Canadian government?

The situation at the international level is highly complex. International politics does not possess any central authority, let alone one that can enforce regulations and mandates. The international system is one in which all kinds of actors, states—international organizations, corporations, nongovernmental organizations, groups, and individuals (including terrorists and criminals)—strive to pursue opportunities and avoid danger.

Because the system is characterized by a lack of agreement on responsibility and overlapping claims to jurisdictional authority, national policy makers confront substantial challenges in such areas as maritime and aviation security. Organizations such as the International Civil Aviation Organization (ICAO) and the International Maritime Organization attempt to play a coordinating role, but issues of implementation remain. Coordinating all these international, transnational, and domestic actors and stakeholders is extremely difficult.

The second development is intermodalism, a recent development that integrates the different transportation modes into a seamless system and uses each mode for the purpose for which it is best suited. It has become a rapidly growing characteristic of transportation systems everywhere.

On the freight side, global freight now moves along a system that links the individual modes of highway, rail, and shipping, and that system is becoming even more integrated because of constant pressures to reduce costs by increasing productivity and reducing inefficiencies. Further, increased customer expectations of both freight and passenger systems extend beyond economic considerations to such areas as environmental impacts. Similarly, passenger systems are becoming increasingly interconnected; airports, for example, are now increasingly integrated with train and metro lines.

Each of these modes has its own approaches to security, so questions of coordination, which are always difficult even when one is dealing with only one mode, are further complicated by a variety of personnel and communication practices and technologies. Moreover, the decision-making structures are still commonly organized by modes, and the key private and public actors continue to think along modal lines, often nationally, an orientation that does not facilitate the implementation of appropriate policies to safeguard any transportation system. It is now essential to view transportation security from an intermodal or systems perspective and to be sensitive to the global reach of transportation systems.

Although transportation must be viewed globally and intermodally, it can be divided into two categories: passenger systems and freight systems. Though they are interrelated, they must be considered separately because each has distinct and separate features that present particular security problems.

Intermodal Passenger Systems

By their very nature, intermodal passenger systems (mass transit, rail, highways, aviation, and maritime) are especially vulnerable because each is complex, large in terms of the areas it covers and the number of people who utilize it, and designed to be easily accessible.

Mass transit. Although there have been several deadly attacks on passenger systems by suicide

bombers, the one on the Tokyo subway in May 1995 by terrorists who deployed sarin gas revealed the kinds of weaknesses that have often characterized passenger systems. These can be summarized as follows: (1) lack of an integrated structure; (2) poor and conflicting information reaching the key decision maker; (3) slow diagnosis and reaction times because subway officials were unprepared for this kind of attack; (4) first responders and hospitals were inadequately prepared; (5) a lack of resources including medicines and effective communications; and (6) poor communication between and among the first responders, their managers, and decision makers, and with the public.

Any attempt to increase the security of a passenger system must therefore take such factors into account. But these involve only the response to an attack. Securing a passenger system also requires (1) clearly defined goals and the use of risk assessment methodologies that link actions to potential threats and costs; (2) criteria identifying key assets and choke points such as bridges, intermodal terminals, and border crossings where their destruction could seriously impact the public welfare or have serious economic consequences; (3) standards for threat reduction at these points; (4) hardening infrastructure at critical points; (5) closed-circuit television (CCTV), biometrics, and other relevant technologies; (6) response plans to handle incidents, including direction and control, communications, and public information; and (7) security education and awareness programs for planners, managers, and operators and for the public.

Many such measures have been implemented to varying degrees in the United States and elsewhere. Additionally, in the United States, Visible Intermodal Protection and Response (VIPER) teams have been deployed at various mass-transit stations.

Highway and rail systems. Highways cover huge distances and encompass thousands of bridges and tunnels that are also prime terrorist targets. However, although it is possible to destroy bridges or tunnels and achieve a symbolic triumph, the damage is localized. Similarly, although difficult to protect, trains run along specific routes and can be controlled. If taken over by terrorists, for example, the train could be diverted from its original route. The same kinds of protective measures as for transit are relevant and could be deployed.

Aviation. Aviation is the passenger system that has received the most attention for many decades and to which most resources have been allocated. It shares many similarities with the surface systems in that it is large and complex and offers easy access. However, the numbers involved are small in comparison to the numbers of passengers using surface or underground rail in many locations, making it possible to screen all passengers and their baggage.

The tragic events of September 11, 2001, when hijacked planes destroyed the two World Trade Center towers in New York and damaged the Pentagon in Washington, led to the adoption of new, far-reaching measures in the United States and elsewhere. The most prominent of these has been extensive passenger screening at airports. However, this approach is extremely expensive, and it is not obvious that it is cost-effective. Tests have consistently revealed that it is still possible to smuggle weapons and explosives past the screeners. More important and effective are new measures such as the installation of reinforced cockpit doors, the deployment of armed marshals, and the arming of pilots to make a successful hijack highly improbable.

Additional measures that have been implemented in the United States and elsewhere include the appointment of federal security directors to all major airports, establishing controls on who can access various airport areas, and background checks of airport workers and staff. In the United States, the attempt to implement an advanced passenger profiling system (CAPPs II) proved quite controversial because it would incorporate private as well as public databases. Subsequently, the VIPER system of behavior profiling was implemented. Bomb detection equipment has also been widely installed.

Attacks can also, and have, come from outside the plane. Surface-to-air missiles, which are readily available throughout the world, pose a deadly threat to any plane because they can be fired from some distance away. How to deal with this threat remains controversial because of the high costs involved in equipping passenger planes with defensive technology.

Finally, general aviation—private planes that can be rented as well as the thousands that are owned by individuals and companies—also raises security concerns. The larger jets can be used as missiles and the smaller planes can disseminate radioactive or

other dangerous materials. Yet, these planes, despite various precautions, remain relatively accessible to terrorists.

Maritime. The first terrorist act against a cruise ship occurred in 1984, when the *Achille Lauro* was hijacked in the Mediterranean Sea. The threat remains, as evidenced by al Qaeda documents decoded in Germany in May 2012. Though cruise ships are attractive targets because of the large number of people involved and the high level of publicity that would be generated by an attack, a successful hijacking requires considerable resources and would have minimal impact economically.

Various measures have been widely adopted to counter such a threat, including baggage and store checks, screening and tracking passengers, and a requirement that U.S. ports be notified of passengers 36 hours prior to arrival. Some lines have initiated security training for crews and may have armed security personnel on board.

Intermodal Freight Systems

Surface transportation. Of all the millions of tons of freight that are carried daily by road, ship, and rail, the most important from a security standpoint are hazardous materials (HAZMAT), a wide-ranging category that includes chemicals, gases, and other materials that are explosive, flammable, toxic, infectious, or radioactive. The most common in the United States is chlorine, millions of tons of which are produced and transported by rail in pressurized tank cars. These present attractive targets because an exploding tank car (caused by an attached bomb) would release a toxic gas with devastating consequences.

Although freight rail security programs have been developed and implemented, numerous problems remain, including the large number of railcars, which may sit unguarded at rail yards; inadequately trained workers; and inadequate preparations for disaster response.

Air cargo. Passenger planes as well as cargo planes carry freight, and here serious issues deserve attention. Such measures as permitting cargo pilots to carry guns, utilizing armed guards on cargo flights, strengthening cockpit doors, and securing the cargo ramps by requiring everyone to undergo a background check all deserve attention. These should,



Passengers undergoing security checks in this highly visible screening area at the new Denver International Airport in 2005. Aviation security changes implemented after the terrorist attacks of September 11, 2001, have included the appointment of federal security directors to every major U.S. airport, improved controls over access to secure areas, and background checks of airport workers and staff. Other additions have included the use of the VIPER behavior profiling system and of bomb detection equipment.

however, be part of a risk-based, comprehensive cargo security plan with deadlines and targets.

Maritime cargo. Millions of containers and a considerable volume of other cargo enter the ports of the world annually. Checking each container or even a statistically significant percentage at a large port is an impossible task; it would bring commerce to a standstill.

Accordingly, the United States has established a number of programs designed to deal with this problem. The Container Security Initiative (CSI) screens cargo before it arrives at U.S. ports and the Customs-Trade Partnership Against Terrorism (C-TPAT) invites shippers to provide data concerning their manufacturing and logistical operations. In return, their goods are less likely to be inspected at the port of debarkation.

Both programs, however, face the problems of verifying the accuracy of vast amounts of information provided by the shippers (a problem aggravated by potential corruption and other forms of criminal activity) and of analyzing it in an efficient and timely manner, so that appropriate action can be taken in regard to high-risk cargo.

The enormous flow of goods aggravates the many security weaknesses inherent in any port's structure and operations, including accessibility by both land and water, the large numbers of stakeholders and workers, and extensive storage facilities. Such vulnerabilities can be minimized through the utilization of such technologies as electronic container seals, sensors to ensure that containers are not opened illegally, conducting background checks of all who access or work in the port and providing them with biometric identification cards, and

using electronics to track trucks and railcars. However, implanting such measures requires adequate financing and coordination by the diverse stakeholders involved.

Conclusion

The most effective way to enhance transportation security is to prevent an attack from occurring. Transportation security, therefore, must be viewed within a larger context—one that recognizes the significance of intelligence, foreign policy, and diplomacy, and is proactive rather than reactive. This means that transportation professionals must now acquire new skills and interact with national security policy makers at the highest levels. Given the need to deal with underlying causes of terrorism and the large overlap between transportation and other critical infrastructures, such coordination is essential.

In the end, however, it is the transportation community that must assume primary responsibility for ensuring that personal mobility and the movement of freight and goods continue as smoothly as possible; failure to do so would seriously hinder national development and future growth everywhere.

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See Also: Airport Security; Emergency Transportation Planning and Operations; Freight Transport, Intermodal and Multimodal; Globalization; Harbors and Port Security; Hazardous Materials Transport; Information Technologies and Transportation; Railroads, Freight; Railroads, Passenger; Transit Systems; Tunnels, Safety and Security Issues in.

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Shared Taxis

A shared taxi, also called a jitney, is vehicular transportation provided to multiple passengers, often on an informal and possibly on-demand basis. There are two major types of shared taxi systems: the jitney system, in which an unofficial vehicle (often a small van) provides service along a more-or-less regular route and for a standard fee, and a second type more analogous to a traditional taxi system and in which a group of people agree to share a vehicle (often a traditional taxicab) for a particular trip; in this type of shared taxi, different passengers may well have different starting and ending points.

Both methods of taxi sharing offer transportation that is more efficient than each passenger driving his or her own car, and more flexible than is typically provided by official, scheduled mass transportation, although they offer challenges in terms of safety. Both systems are in use all over the world today and are particularly useful in areas where the supply of transportation from official services does not meet the demands of passengers.

History

Shared taxis date back to the early days of the automobile. Although some see the roots of the jitney system in a streetcar strike in Phoenix, Arizona, in 1913, the first broad application of this system of transportation dates from 1914. In that year, partly as a way to make money during an economic downturn, automobile drivers in Los Angeles, California, began offering rides in their cars for the price of a nickel, or "jitney." Soon informal routes developed, often paralleling streetcar routes, and provided a transportation alternative to the streetcar

for people who did not own a car. A distance-based fare structure developed so that higher fares were charged for longer trips.

The jitney system became popular in Chicago in 1915, during a streetcar strike, when many people used shared cabs to get to Chicago's Loop (downtown). The Chicago system proved so popular that the city government tried to regulate it, creating assigned routes and requiring jitneys to carry signs with their prices and routes, but it was largely unsuccessful.

Although the jitney system rapidly spread across the country, the unplanned experiment in Chicago also showed one of the problems with replacing mass transit (streetcars) with relatively small-capacity automobiles in a densely packed urban area: extreme traffic congestion as large numbers of people tried to get around a relatively small geographic area more or less at the same time. The informal nature of the jitneys also raised issues about safety, the economic viability of the system, and, particularly in segregated areas, how to provide services to passengers of different races.

Present-Day Shared Taxi Systems

Two types of shared taxi systems are common today. In one, a system of small vans or similar vehicles provides service similar to that of municipal buses, along routes that are known to residents of the area, even if they are not officially recognized by the local government.

In the other, individuals choose to share a taxi from an airport or another starting point, perhaps by using a mobile app or Web site to find available transportation, but there is no expectation that the taxi will follow a similar route on each trip. Instead, the route is based on the needs of the particular group of passengers at the time.

The first type of shared system is common particularly in suburban areas, the less dense areas of large cities, and as feeder systems to official organized transportation systems in the central urban areas. For instance, Queens, a borough of New York City, has long had a system of "dollar vans" running along major streets and linking people to subway stations and other common destinations. A similar system exists in the northern New Jersey cities that are relatively close to New York City but inadequately served by official municipal transportation systems.

This type of shared taxi system is sometimes seen as threatening to official local transit, because passengers using the unofficial system are presumably being "siphoned off" from the official system, thus lowering ridership. Because official transit systems are relatively inflexible in terms of making route changes and often have higher operating costs because of administrative overhead, safety requirements, and other issues, the unofficial vans are often seen as unfair competition. In addition, because the unofficial vans are often largely unregulated, they may be seen as less safe. They also could pose a potential burden to the public if they do not carry sufficient insurance.

Some researchers have suggested that this type of shared taxi might be particularly useful in suburban areas, where traditional transit systems nearly always run at a deficit due to low population density. The relative flexibility of private providers offers an advantage in that they are likely to find the most efficient and profitable routes, although leaving an area entirely to the private sector could result in limited or no service for elderly or disabled residents, people in poverty, or those whose homes are too far from the profitable routes.

The second type of shared taxi service involves a group of passengers agreeing to share a taxi for one trip and splitting the cost of the ride. This type of shared service is common at major airports, where there may be a dispatcher or taxi marshal assigned to group passengers into cabs. Such systems are somewhat formalized when the transportation authority provides passengers with lists of fixed prices for various destinations, and the marshal may also be in charge of preventing unlicensed cabs from picking up passengers.

Mobile technology is now enabling people, taxi companies, and/or municipal governments to create online booking systems or cell phone applications to enable passengers to book a cab or enter their origin and destination points and find others who will be traveling along similar routes and are willing to share a cab.

New York City began allowing licensed taxi cabs (those ubiquitous yellow cabs) to provide shared rides in 2010. Passengers gathered at group taxi stands and organized themselves into cabs going to a common destination. However, the service proved unpopular, perhaps because a wide range of transportation options were already available in the city.

Shared taxis have been more successful in areas where there are fewer options, including suburban Montreal, Quebec, and Sun Prairie, Wisconsin; the latter is a small town near the state capital that has no municipal bus system but provides subsidies to private shared taxi services offering door-to-door transportation.

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See Also: Bus Routes; Jitneys; Taxicabs; Transit Planning, International; Transportation and the Disadvantaged.

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Ships

A ship is a watercraft used for the transport of cargo or passengers. Though "ship" originally referred to a sail-driven craft with a particular type of rigging, today it refers to any large watercraft. The difference between a ship and a boat is simply one of size, although there are some exceptions—riverboats, ferryboats, and submarines are considered boats regardless of size.

Ships are referred to in the female gender in the maritime trade, in casual use, and in some formal

style guides. Ships usually have individual names, and, despite the convention of a ship being female, the name may be female, gender-neutral, or male (e.g., military ships are often named for former presidents or generals).

Ships and boats are among the oldest forms of transportation, and their uses in fishing, whaling, and transportation of goods across waterways were key to the development of human civilization. Many early settlements were founded by seafaring people from other lands, and critical historical developments have been wrought by waves of such people introducing cultural and material novelties to new lands or colonizing them.

Among the host of colonizers who arrived by ship are the Vikings of the early Middle Ages, who sailed throughout Europe and far northern North America, and the Europeans who created trade routes and colonies throughout the world from the 15th century on. Marine travel was also critical in the development of scientific understanding of the world. As the sciences of navigation and mapmaking were being refined, the compass and optics were developed in support of sailing, and ship design evolved as understanding of mechanics improved. Ship travelers all over the world introduced their cultures to new ideas, new foods, and previously unknown forms of life.

The hull of a ship is the foundation of its architecture, and buoyancy is achieved by the hull displacing a greater weight of water than the weight of the ship. Ships do not glide on the surface of the water but, rather, sit upon the water with much of the ship submerged beneath what is visible. Compartments in the hull are used to hold ballast water, providing weight that helps stabilize the ship by making it bottom-heavy.

The foremost part of the hull is the bow, while the keel extends along the length of the ship at the bottom of the hull and provides stability and longitudinal strength. In the Anglo-American shipbuilding tradition, the construction of the ship begins with laying down the keel. Propulsion systems are usually mechanical today, with sail- and human-powered propulsion generally used only for small boats. Mechanical propulsion systems usually use a diesel engine to drive one or more propellers, for which there are numerous designs. Steering is accomplished by the lateral force enacted on the water by a rotating rudder.

Ship Classification

Many modern ships belong to a ship class, consisting of ships of a distinctly similar design, within a specific ship type. In the U.S. Navy, ship classes are named for the lead ship in the class, which, by extension, usually means the ship with the lowest hull number.

The Nimitz class of super-sized carriers consists of 10 nuclear-powered aircraft carriers, the lead ship of which is the USS *Nimitz*, named for Admiral Chester Nimitz, the Pacific fleet commander during World War II. Within that class are two subclasses, the Theodore Roosevelt class, which incorporated slight improvements on the original (1975) design of the class, and the Ronald Reagan class, which incorporated some of the features that were later used in the class that succeeded the Nimitz, the Gerald R. Ford class.

Merchant ships are classed by classification societies such as the American Bureau of Shipping, which employs engineers and surveyors to inspect ships and classify them according to factors including their structure, stability, and safety, with respect to their purpose. For this reason, merchant ship classes are often more descriptive than the Navy's, such as "oil tanker," or "mixed cargo carrier."

"Ice class" is a class notation that reflects the ship's ability to function amid sea ice. The American Bureau of Shipping includes a hierarchical set of ice classes, A5 through A0, followed by B0, C0, and D0, from strongest to weakest. The strength of the rating indicates the degree to which the hull has been strengthened to withstand pushing through sea ice.

Greater structural integrity is guaranteed through the use of scantlings-girders, bulkheads, and beams; and at the highest classes, the hull is fitted with sea bays and sea chests for seawater intake, as well as protection for the propellers and rudder (or use of azimuth thrusters). Fuel tanks also require heating to prevent fuel from becoming a gel at Arctic temperatures. Ice class ships include but are not necessarily icebreakers, which are ships specially shaped and powered to clear ice in order to make a path for merchant ships. Icebreakers are key to keeping trade routes traversable in the Arctic region.

There are a wide variety of ships built for special purposes, such as rescue boats, various types of research and survey vessels, fishing vessels, weather ships, and pilot boats. Naval ships are built



Canadian Coast Guard ship Louis S. St-Laurent and the U.S. Coast Guard cutter Healy in Arctic Ocean ice during a joint survey of the Arctic continental shelf on September 5, 2009.

in accordance with their purpose and relationship to combat. Generally speaking, commercial ships can be divided into two types: passenger ships and cargo ships. Passenger ships include ferries, ocean liners, and cruise ships, any of which may also carry a certain amount of freight or cargo, although they are not designed to do so as their primary purpose (and, so, they typically lack special cargo-handling equipment such as cranes).

Cargo ships come in various specialized types according to the type of cargo they are designed to transport, such as oil tankers or chemical tankers for liquid cargo, bulk carriers or general cargo ships for dry cargo, container ships designed to carry standardized shipping containers, and others. Today's modern cargo ships require properly designed ports, canals, and inland waterways to

facilitate their travel and docking, and specialized facilities for loading and unloading their freight.

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See Also: Containerization/Container Shipping; Ferries; Inland Waterways, Planning and; International Waters; Maritime Industry; Ocean Passenger Travel.

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Sidewalks

Sidewalks accommodate nonmotorized travel, which has become increasingly more important because of environmental and health-related problems of automobile-dependent societies. Therefore, accessible, safe, and comfortable sidewalk and crosswalk design is an essential component of a comprehensive transportation planning agenda.

The national standards for sidewalks and crosswalks are provided by the Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities (ADAAG). The Institute of Transportation Engineers (ITE) and the American Association of State Highway and Transportation Officials (AASHTO) also provide recommendations.

Pedestrian presence in public rights-of-way requires access, safety, and amenities for comfort. Sidewalks and crosswalks are two areas of public rights-of-way that provide these conditions for the pedestrians. Access relates to circulation of all pedestrians with ease on sidewalks and while crossing a street. Safety refers to traffic safety and crime safety. Pedestrian amenities include landscape

elements, street furniture, streetscape amenities, public art, and "parklets" or small, park-like areas.

Access

For circulation of all pedestrians, the width without obstacles (clear width), grade, and surface quality of sidewalks are considered.

For an average person, the required clear width for standing is 1.5 to 2 feet, and for walking comfortably, it is 3 to 4 feet. For two people walking side-by-side, 5 feet of unobstructed width is required. For wheelchair access, 3 feet of unobstructed width is required on a public right-of-way. If the clear width is less than 5 feet on any route, a passing space with 5 feet of clear width must be provided at reasonable intervals, not exceeding 200 feet. A person with a service animal or a sighted guide uses 4 feet of width. Therefore, accessible sidewalks are a minimum of 5 feet wide on local streets in residential and commercial areas. In central business districts, the width of a sidewalk should be approximately 10 feet.

Grade is the degree of inclination of the slope parallel to the direction of travel. It is the ratio of the change in elevation to the distance covered. A running slope, which is the average slope along a continuous slope, should not exceed 1:20 (5 percent) with ramps not exceeding 1:12 (8.33 percent) where necessary. Cross-slope is the slope measured perpendicular to the direction of travel. It should be measured every 2 feet, which represents the stride of a person or the wheelbase of a wheelchair. The cross-slope of a sidewalk should not exceed 1:50 (2 percent).

The type of surface material on which people circulate is a matter of access, as well. Firm and stable surfaces, such as concrete, are preferable for durability. Slip-resistant surfaces are necessary for safety. Efficiency of movement for pedestrians or for people with disabilities is improved on firm, stable, and slip-resistant surfaces; on such surfaces, people spend their energy mainly for horizontal movement. Changes in level, which refer to the height changes between adjacent surfaces, are problematic for accessibility. Examples of level changes include curbs (without curb ramps), grooves in concrete, heaving, tree root infiltration, and small steps, among many others. Maximum vertical level change is one-quarter inch.

Grates are another example of level changes. A grate is a permeable framework of latticed or

parallel bars allowing liquids and small objects to go through. Maximum width of gaps on a grate is one-half inch in the direction of travel. The maximum gap at a rail flangeway is two and one-half inches.

Curb ramps, which have several components and types, are also crucial for access. There are five components of a curb ramp. (1) The landing is the part on the sidewalk at the top of a curb ramp. (2) The approach is the section adjacent to the landing on the sidewalk. (3) The ramp is the sloped transition between the street and the sidewalk. (4) The flare is the sloped transition between the ramp and the sidewalk. (5) The gutter is the dip along the edge between the street and the ramp. An accessible curb ramp has a ramp at least 3 feet wide and a 4-foot-wide landing in a perpendicular curb ramp form or a 5-foot-wide landing in a parallel curb ramp.

The four types of curb ramps are perpendicular, parallel, diagonal, and built-up. The perpendicular curb ramp is located within the border width, is oriented at a 90-degree angle to the curb line, and is usually installed in pairs at a corner. The diagonal curb ramp is located at the apex of the curb radius to serve both crossing directions at once. The parallel curb ramp, or an in-line curb ramp, is all or part of the sidewalk ramping down to a street crossing. The built-up curb ramp extends from the sidewalk with flared sides blending down to the street surface and blocking the gutter. Both parallel and built-up curb ramps are considered suitable for narrow sidewalks. A recent trend is to combine these curb ramps with partial or full curb extensions to improve the safety of crosswalks.

Crosswalks are particularly important for pedestrian access because crossing time and different types of crosswalks provide various levels of access and safety. A crosswalk is a designated passage for pedestrians to cross the street. Therefore, crossing time plays an important role in the efficiency of a crosswalk. The walking speed for an average adult is assumed to be 4 feet per second when signal timing is adjusted. However, for children, seniors, and people with disabilities, the walking speed goes down to 2 feet per second. Moreover, most people walk slower than 4 feet per second, even though it is the industry's standard.

Some crosswalk types provide better access and safety than others. Crosswalks are usually located at the intersection of two streets, but sometimes

in midblock. In either location, crosswalks may be marked or unmarked, although marked crosswalks provide better safety for pedestrians. Also, in either location, the accessibility and safety of crosswalks are enhanced with partial or full curb extensions. The curb extensions at the intersections are also known as neckdowns. The curb extensions are beneficial because they calm the traffic, shorten the crossing time and distance for pedestrians, and improve visibility for both drivers and pedestrians. Similarly, medians and islands provide refuge from the traffic for crossing pedestrians.

Medians separate opposing lanes of traffic; islands are protected spots for pedestrians on crosswalks to wait before they continue crossing. Also, in grade-separated crossings (that is, overpasses and underpasses), pedestrians and motor vehicles are allocated to different levels. The grade-separated crossings, however, provide poor mobility compared to other crosswalk types. When medians, islands, and crosswalks are raised only, their visibility increases without affecting mobility.

Safety

Traffic safety is addressed in sidewalk design through arrangement of different zones of sidewalks and traffic calming measures. There are three zones of a sidewalk: (1) the effective width or walking zone, where movement effectively takes place; (2) the shy zone, the shy distance, or building zone where pedestrians avoid walking due to proximity to buildings, retaining walls, fences, etc.; and (3) the curb zone, furniture zone, or planting strip where landscape elements, street furniture, and streetscape amenities are mostly placed. Sidewalk arrangements provide better protection for the pedestrians from traffic when the curb zone is between the walking zone and the road bed. Curbside parking enhances the traffic safety level of this arrangement.

Traffic calming measures include the curb extensions, road diets, raised crosswalks, speed bumps, use of the proper level of lighting at the crosswalks, effectively placed signage, and various types of beacons allowing pedestrian control for crossing. Curb extensions and road diets rely on slowing down the traffic by narrowing the road bed and/or the traffic lanes. Raised crosswalks and speed bumps help lower the speed of traffic. Lighting crosswalks adequately makes the crosswalks more visible to the drivers, which also slows down the traffic.



A curb extension, also known as a neckdown at an intersection, narrows Broadway as it approaches 33rd Street in Herald Square in New York City. Curb extensions can increase the safety and visibility of crosswalks, shorten crossing time, and calm traffic.

Signage and various types of beacons, such as a rectangular rapid-flash beacon and a pedestrian hybrid beacon, help increase the visibility of crosswalks and lower the speed of vehicles. A rectangular rapid-flash beacon uses rapidly flashing rectangular-shaped LED lights that are mounted on the crossing sign. Similarly, a pedestrian hybrid beacon is used at an unsignaled location with a marked crosswalk.

Crime prevention through environmental design (CPTED) addresses crime safety on sidewalks. The key concepts are territorial reinforcement and natural surveillance, as well as lighting for security.

Territorial reinforcement is having a sphere of influence around a person where territorial control is established. The familiarity with that territory and its users reinforces that territory in a way that a potential intruder would be discouraged. Along

the same line of thought, natural surveillance is designed to maximize visibility of publicly available spaces so that potential intruders are observable. Because of territorial reinforcement, the potential intruders are also recognizable. These concepts help designers create defensible sidewalks where high visibility and high control discourage a potential offender. Lighting for security is another way of achieving high visibility for the same purpose.

Pedestrian Amenities

Although they make a walkway more attractive and pleasant, pedestrian amenities are considered as obstacles and protruding objects from the perspective of accessibility because they may limit the clear width of a sidewalk by intruding into the walking zone. Therefore, the location of landscape elements, street furniture, streetscape amenities, and public art is crucial in the design of sidewalks.

Landscape elements include street trees and other plants that add visual and seasonally varying appeal to the sidewalks and help improve air quality. Yet, maintenance of landscape elements may be difficult and expensive. For visibility purposes, communities establish standards for the distances between intersections and trees. Vertical clearance and grates, which are used as tree guards, are other issues related to street trees. Landscape elements are usually placed in the curb zone.

Street furniture—such as benches, chairs, tables, kiosks, and transit stops and shelters—provides functionality, human scale, and definition. Most street furniture elements are fixed in place, although some of them may be movable. Coordination of street furniture placement improves their efficiency. They are also usually placed in the curb zone, although depending on the land use, some street furniture may be located in the building zone. For example, restaurants place tables and chairs in the building zone.

Streetscape amenities include street lights, signage poles, trash receptacles, newspaper racks, bollards (vertical posts), utility-related structures, public phones, parking meters, and fire hydrants. The location of streetscape amenities in relation to each other may make the pedestrian environment cluttered. Street lights are important to establish desired illumination levels for safety reasons. Location of street lights in relation to street trees affects the level of illumination because tree canopies may

block the street lights. Streetscape amenities are usually placed in the curb zone, as well.

Public art is another visually appealing pedestrian amenity, which also helps strengthen local identity. In addition to sculptures, murals on the walls or on crosswalks are especially useful as traffic calming measures.

Parklets are fast spreading as contemporary pedestrian amenities. A parklet is a small pedestrian space achieved by conversion of an automobile space into an activity area for pedestrians. They are on either commercial or residential streets. So far, implemented parklet examples have been built through conversion of several types of automobile spaces. One type of automobile space is parallel or diagonal parking spots on streets; another one is a traffic triangle, and a full lane. They accommodate a variety of pedestrian activities. Some parklets are built and maintained by businesses, such as cafés and restaurants. Some of them are outdoor exercise courts; some are for plants only, and some for sitting only.

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See Also: Pedestrian Safety; Pedestrian Safety, Blind and Elderly; Pedestrian-Friendly Design; Road Diets; Road Surface Marking and Markers; Traffic Calming.

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Single-Occupant Vehicle Trips

Convenience and habit can be said to be powerful forces in human affairs. The phenomenon of single-occupant vehicle (SOV) trips offers abundant evidence to support this thesis. Culturally, the automobile has been promoted and marketed for approximately 100 years as an instrument of individualism, independence, self-gratification, and ego enhancement. By identifying with these potent qualities long ago, the automobile became an icon of mobile identity, one that could be interpreted as reinforcing its use in the single-occupant mode.

Structural Underpinning

It would be very difficult for many individuals to become habituated to perpetuating SOV trips if not for the vast edifice that has been constructed in major industrialized nations to support this ability and choice. Economies of scale had to be assembled in order to bring the prices of automobiles into the range of affordability for masses of people. Roadway networks had to be constructed and maintained. Fuel, parts, equipment, and services to support automotive culture had to be distributed to large and small population centers in every type of terrain and climate zone. Administrative, licensing, regulatory, and law enforcement agencies and staffs had to be concentrated and trained.

All of this meant taxes, fees, and funding channels had to be devised and implemented. And the industries of image-burnishing had to be enlisted, paid, and employed to promulgate the ideal of individual, liberated drivership.

Each of these elements has in fact occurred in many parts of the world. The number of vehicles in operation worldwide surpassed 1 billion in 2010, according to various researchers. About one-fourth of those were in the United States, where the ratio of cars to people has reached approximately eight

motor vehicles for every 10 people, exclusive of motorcycles and other two-wheelers.

The automotive social and physical support structure also extends to work arrangements. For all the discussion of the trend of telecommuting and all the investment in mass transit, fewer than 6 percent of workers use public transit to commute, according to the American Community Survey conducted by the U.S. Census Bureau—and almost 80 percent of Americans working outside their home drive to work alone.

Preference Patterns

It has been shown through extensive research that drivers consistently make SOV decisions based on convenience, a sense of reliability, flexibility, and general comfort and satisfaction. While many drivers who elect to operate in SOV mode have sampled the various carpool and public transportation options available to them in their vicinity, it takes little in the way of an unforeseen delay, dislocated schedule, or perceived safety risk to influence subsequent decisions toward the private vehicle option, and that most often leads in particular to an SOV trip.

Many drivers are aware of the cost trade-offs but are willing to make sacrifices in other parts of their household budgets in order to preserve their preferred SOV practices. Obviously, this route is easier for more affluent car owners.

Outside of the work commute—by far the most common use of a private car—the second most frequent use of private automobile travel is commuting to a school. Much as it can be for workplace decisions, dependence on the use of a car is a chief determining factor in the choice of educational venues to attend. A person or family can relocate to a desired neighborhood that may be distant from a preferred school—yet, without making any particularly inconvenient arrangements, the individual in question can still commute to that school by means of an SOV trip. From among other forms of discretionary travel mode selection, it is sometimes a personal lifestyle choice to travel alone by car—for example, when on a leisure trip.

Inducements and Incentives

Some local transportation authorities, parking operators, and institutional stakeholders offer inducements for their stakeholders, employees, or

members to doubleup, carpool, avail themselves of mass transit, or otherwise elect options other than SOV travel.

To take one example among a myriad of such programs, the University of Washington charges \$423 on a quarterly basis for SOV permits for faculty and staff (and slightly less for students) to utilize on-campus parking facilities. For the same price, a carpool group of three individuals can avail themselves of the same parking facilities—but they will split the cost three ways.

Alternately, the university promotes its U-PASS mass transit permit as a virtually free benefit component of its standard student activities fee; it has a nominal price of \$76 per quarter. U-PASS provides full-fare coverage on multiple mass transit systems and lines of service, discounted ride service on additional lines, and discounted carpool parking, vanpool fare credits, and discounts on bicycle safety equipment as well as at various merchants. In other words, the University of Washington has heavily disincentivized SOV travel as a choice of commuting mode among its student body.

Such programs may have a compelling impact over the long term, as collegial environments can tend to reinforce collective behavior. Even in the generally less congenial milieu of the workplace, employer subsidies of mass transit usage by employees can also help condition the individual to rely on mass modes of commuting as opposed to stepping back to SOV trips once such a subsidy is left behind as a result of job change or venue relocation.

Hybrids and HOV

It is widely considered that experimentation with high occupancy vehicle (HOV) lanes on highways have been less than an outstanding success in fostering the adoption of carpooling behavior by the great mass of commuters. HOV lanes do provide some congestion-relieving benefits under certain conditions on some highways. However, there are shortcomings to the technique, and quite often one outcome is greater congestion on the remaining lanes than there would otherwise be if the HOV lanes were opened to SOV travelers. Ironically, this is especially evident during peak rush hour times.

In some quarters, in the interest of environmental benefits among others, it has been proposed to permit hybrid-type SOVs to operate in HOV

lanes, under the reasoning that drivers should be rewarded for investing in hybrids and for the very real benefit that they deliver over regular internal combustion engine vehicles that make up almost the total volume of vehicles on the roadways.

At least one study, conducted during a recent 15-month period on segments of major commuter arteries in California, showed no negative impact on HOV lane operations or overall highway traffic flow by allowing hybrid SOVs to operate in the HOV lanes—even when the hybrids approached a threshold of approximately 20 percent of the total HOV-lane traffic. (The hybrids were identified by yellow stickers distributed free to some 85,000 owners of various models, such as the Toyota Prius.)

This somewhat lengthy experiment was conducted in part because the state transportation authorities in California had been considering implementing the hybrid-SOV-in-HOV proposal on a permanent and widespread basis. It ended, however, in mid-2011. Researchers and policy makers harbored the concern that SOV hybrids could one day in the not-too-distant future surpass the capacity of HOV lanes to sustain them, and a policy reversal at that point would be far more difficult to execute, as precedent would have been set and would have been operating for some years—never an ideal scenario for policy reversal.

The trial became more complicated, however, when the state launched another SOV-in-HOV program with free white stickers to 22,000 zero-emission, all-electric, or compressed natural gas vehicles—and then still another variation on the test, this one set to operate through January 2015, featuring free green stickers being given to up to 40,000 electric plug-in vehicles such as the Chevrolet Volt.

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See Also: Automobile Culture; Automobile Trips; Carpool Programs, Ridesharing and; High Occupancy Vehicle Lanes; Privately Owned Vehicles.

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Smart Cars

Smart cars, referred to also as autonomous, self-driving, robotic, autopilot, driverless, auto-drive, automated guided vehicles (AGV), or iCars, are capable of driving by themselves using artificial intelligence and mechatronics (the integration of electronics, control, software, and mechanical engineering). While many of the cars on roads today have a degree of automation (for example, temporary auto-pilot functions, cruise control, adaptive headlamps, lane departure warning systems, and automatic parking), vehicles relying entirely upon automation (fully autonomous) are predicted to be on the market within the next decade.

The term *smart vehicles* refers to vehicles equipped with a level of automation or artificial

intelligence. Semi-autonomous vehicles require an operator, whereas a fully autonomous vehicle can handle all aspects of driving, maneuvering, and accident avoidance. The vehicle is able to completely manage itself from point A to point B, without any human intervention, regardless of the situations which arise. Vehicles equipped with artificial intelligence software have the ability to sense objects close to the vehicle and mimic the action that would usually be taken by a human.

Google has been working on smart cars since 2010. This sits logically with its work on mapping and software. Google's driverless car project maintains a test fleet of seven cars (one Audi TT and six Toyota Priuses) that has driven over 500,000 miles. Google and the automotive industry are developing robotic prototypes using wireless technology. The first benefit of smart cars is that they should be able to offer improved road safety and reduce traffic accidents, injuries, and deaths. In fact, Google estimates that robotic cars could reduce the number of road deaths each year significantly. The global total of road deaths was 1.24 million in 2011, 37,000 of which occurred in the United States, 27,375 across the European Union (EU), 143,000 in India, and over 70,000 in China. Robots, according to engineers, react faster than humans because they have 360-degree perception and do not get distracted, sleepy, or intoxicated.

Smart cars can drive more intelligently than non-autonomous cars. They can implement eco-driving techniques, which reduce consumption of gasoline and other finite fuels and, as a result, reduce costs to the car owner. In this way, smart cars are considered a positive addition to carbon reduction and climate change mitigation.

Futurist Randall Parker suggests that robotic cars will make electric cars more attractive and economically viable. He sets out three reasons for this. First, electric robotic vehicles can take themselves to recharge stations and batteries could then be smaller and cheaper. Second, electric robotic vehicles could carry more people per day because they could be routed from one individual to another, like a taxi, when a rider uses a mobile device to signal a need for a ride. This reduces vehicle miles traveled and increases productivity and efficiency for the vehicle. Last, electric robotic vehicles could park themselves at the periphery of urban areas until required. This reduces congestion and parking costs.

The autonomous car's smartness comes from a series of sensors that are positioned strategically about the vehicle. A rotating sensor on top of the car scans a minimum of 200 feet (61 meters) in all directions. This generates a precise three-dimensional map of the car's surroundings. The ability of the smart car to detect and react to moving obstacles such as other traffic, pedestrians, and traffic signals relies upon a camera adjacent to the rear-view mirror that communicates information to the car's onboard computer.

Cameras are used to, for example, distinguish lanes. Global positioning units are used to determine the car's location by getting information from satellites and ultrasound sensors to detect obstacles in front and to the back of the car; these are particularly important for parking. How a car drives and reacts can be programmed for different driving personalities—the programmed personality could be cautious and risk averse or confident and bullish—and the personality chosen would determine whether a car gives way to another vehicle, for example.

Benefits and Risks

While smart cars offer a number of benefits, they are not without limitations and risks. Smart cars operate through an intricate web of artificial intelligence, so inevitable faults can develop with the technology-causing accidents or damage. In addition, private maintenance of the robotic vehicle may be cost-prohibitive because of the high-level engineering and software technologies involved, which escalate costs.

The convenience of the vehicle may enable passengers to use their travel time in a way that increases their efficiency, but it could also result in complacency and over-reliance on automation, which could mask signs of faults or glitches. It was argued that smart cars may contribute rather than relieve congestion as owners send their cars off to do more tasks, and the owners themselves may grow less healthy if the cars' convenience discourages exercise.

A number of challenges lie ahead for smart cars. The car manufacturer Ford has made it clear that the main barrier, in addition to affordability issues, to commercialization of the autonomous car is customer acceptance. Trust in the technology seems to be the sticking point. Through a series

of clinics and polls, Ford has found that people are uncomfortable with the idea of surrendering control of their vehicle to a computer, although they are receptive to greater intelligence within the car, such as a collision warning for safety and automatic parallel parking. In an attempt to acclimate customers to automated vehicles, Ford has introduced the new Ford Fusion, which is the first affordable sedan to be equipped with a lane-keeping system.

The biggest unresolved issue to be addressed prior to mass commercialization of smart cars is liability. Individual states in the United States, namely Nevada, California and Florida, are already preparing themselves for the future uptake of smart cars by introducing legislative measures that allow autonomous vehicles to operate on public roads, but these do not address issues of who is legally responsible for an autonomous vehicle that has caused an accident or highway offense. Is it the owner of the vehicle, the manufacturer, or the software developer?

Potential solutions to the issue of liability vary but could include the introduction of laws limiting the liability of robotic manufacturers. Because of liability concerns in the United States, the European Union, and other countries with complex legal regimes, many in the automotive industry predict that China will become the first major market for smart cars.

A further challenge to the operation of robotic cars in current transport systems is the need for them to be able to coexist with cars driven by humans (that is, nonautonomous cars). Autonomous cars will be able to communicate with each other, but they will be less capable of determining or predicting the actions resulting from the more intuitive and improvisational driving techniques of humans. Some conversations around managing the coexistence of autonomous and non-autonomous vehicle technologies propose the development of special roadway lanes for smart cars. However, this poses planning, development, and land use issues and could trigger further discussion on the negative environmental effects of greater road construction.

The idea of self-driving cars as a means of reducing accidents and congestion has been around for a long time. One of the most popular exhibits at the 1939 New York World's Fair was Futurama, a



This rotating sensor installed on top of an autonomous Volkswagen Junior 2 in 2009 used 64 laser beams to scan the surroundings in all directions, collecting 1.3 million three-dimensional datapoints per second.

depiction of a city with cars remotely controlled by radio. In the 1980s and 1990s, the European Commission sponsored a program of research on automated driving called Prometheus. The Prometheus project on autonomous vehicles commenced in 1987 and ran until 1995. Outputs were the twin robot vehicles VITA-2 and VaMP developed for Mercedes-Benz by a team with the Bundeswehr University of Munich.

In the mid-2000s, the Pentagon's research arm, the Defense Advanced Research Projects Agency (DARPA), launched its Grand Challenges, offering prizes to inventors of driverless cars that did best at navigating a tricky course.

Commercialization

The commercialization of smart cars that are fully autonomous is just years away. The technology exists and is being robustly tested, particularly in Nevada and on autobahns in Germany. Researchers at Oxford University are testing the self-piloting of a Nissan Leaf controlled by an Apple iPad in the

dashboard. It is guided by a low-cost navigation system that assesses its surroundings using cameras and lasers built within the body. The iPad can issue a prompt to offer the driver the opportunity take the wheel and then switch back to autonomous mode by touching the screen.

The 2014 Mercedes-Benz S Class, revealed in May 2013, has all the technology built in to operate fully autonomously. However, due to outstanding legislative issues, the technology will be programmed not to operate, at least in the short term. Undoubtedly, legislators and administrations are tuned in across the globe to smart-car developments. The potential benefits appear to justify the costs of implementing and accommodating this forthcoming revolution in passenger road transport.

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See Also: Automated Vehicle Guidance Systems; Automated Vehicle Monitoring Systems; Automobile Accident Avoidance Systems; Automobile Design; Electronic Route Guidance Systems; Emerging Technologies; GPS, Automobile.

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Smart Growth

The prevailing pattern of urban growth, particularly in the United States, is in the form of sprawling, auto-oriented, low-density development, mostly in the suburbs and outer edges of metropolitan regions. Beginning in the 1990s, proponents of smart growth sought to change this pattern of development by seeking ways to concentrate urban growth at higher densities and closer to the traditional urban core.

By definition, "smart growth" refers to those policies and planning strategies that build communities in a compact way, and with a variety of housing and transportation choices near employment, schools, shopping, and other amenities. Typically, the focus of smart growth is on managing urban development at a regional scale in ways that offer a better balance between where housing, amenities, and jobs are located within a metropolitan area. Thus far, the focus of smart growth policies has been the United States, although recently, an alliance of various organizations in the United Kingdom agreed on a set of principles promoting smart growth policies adapted to conditions in that country.

As an urban planning model, smart growth has a number of key goals. These include the following:

1. Developing mixed-use, dense, and walkable communities
2. Reinvesting in existing infrastructure in older communities
3. Promoting transit-oriented development that encourages the use of public transportation and reduces reliance on the automobile
4. Developing a range of housing choices and styles
5. Preserving open space, farmland, and environmentally sensitive areas
6. Enhancing a community's sense of place

Those who promote smart growth goals include environmentalists, urban planners, and some politicians and policy makers, as well as advocates of public transit and central-city living.

Smart growth communities are sometimes labeled new urbanist. Smart growth and New Urbanism are described synonymously, but they are in fact distinct. Smart growth originated out

a concern for the environment and is very policy driven and policy focused. New urbanism, on the other hand, is more design-oriented, originating from the fields of architecture, urban design, and physical planning.

New urbanists focus on changing the physical shape and orientation of communities to include sidewalks for walkability, a variety of housing styles, mixed-use development, and opportunities for the incorporation of public transit. The goals of smart growth and new urbanism are very similar but their approaches are quite different. New urbanists focus on community-scale planning and design options to create neotraditional-style developments. Smart growth advocates focus on introducing policies at a regional scale to guide compact development toward more central locations.

In this regard, strategies used in the promotion of smart growth include offering incentives such as density bonuses, grants, and funds for infrastructure provision in ways that encourage the market to intensify urban development in certain locations. Incentives are at the heart of smart growth policies. The following is an example of what considering the transfer of development rights (TDR) program means.

TDR programs are fairly recent market-based tools in the smart growth toolkit. These programs establish a transfer system where, a property owner sells his or her development rights, typically to a developer, who then uses these rights to build in a different location. The land from which the development rights are sold remains preserved from development with an easement. The location where the developer is allowed to build is referred to as the “receiving area.” The developer can build typically at high densities in these designated areas. The supply and demand for TDRs will depend on the profitability of development and the demand for higher density in designated receiving areas.

History of Smart Growth

The specific origin of the term *smart growth* is uncertain, but there were a number of important events that led to the establishment of smart growth principles as elements in urban and regional growth management. Each of these events took place in the mid-1990s. First, the American Planning Association (APA) produced an influential report in 1996 titled *Growing Smart Legislative*

Guide: Model Statutes for Planning and the Management of Change, offering governments “practical tools” to prevent urban sprawl and at the same time protect farmland and open space. The APA updated this guide in 2007.

The main audience for the *Growing Smart* report is state government officials, such as governors, state legislators, state legislative research staff, state planning agencies, and other state-level offices, as well as officials engaged in various aspects of land use planning and growth management. The APA’s *Growing Smart* guidebook offered a number of recommendations related to state zoning reform and state regulatory responsibility. While zoning and land use regulation remains the primary domain of local government, the *Growing Smart* guidebook encouraged state-level interventions.

In a similar manner and around the same time, the Natural Resources Defense Council (NRDC), a nonprofit environmental advocacy organization, produced the *Toolkit for Smart Growth*. The Surface Transportation Policy Project (STPP) was an important partner in the development of NRDC’s smart growth toolkit. This nonprofit organization promotes an increase in the availability of varied transportation choices, including walking and public transit. The *Toolkit for Smart Growth* focused on ways to promote higher-density development, increased transportation choice, and other smart growth planning initiatives.

In 1996, the U.S. Environmental Protection Agency (EPA) established a network of various agencies interested in smart growth development. This was another key event in the history of smart growth. The EPA is a federal agency charged with monitoring, setting standards, and regulating to protect the natural environment. Smart growth planning and policy aims to protect the environment from any negative impacts of urban development and sprawl.

According to many research studies, sprawling development creates environmental problems, including increased air pollution; higher energy consumption; loss of open space, farmland, and species habitat; shifts in patterns of local and regional species diversity; storm-water runoff impacting stream ecosystems and water quality; and increased risk of flooding. The EPA, through its Office of Policy, established a clearinghouse of news, research, presentations, and other resources

to provide information on smart growth related topics to the public, government agencies, scholars, and students. A number of publications are produced through the EPA's Smart Growth Network, including a 100-page primer titled *Getting to Smart Growth: 100 Policies for Implementation*, which offers concrete techniques to implement smart growth principles across different jurisdictions. The Smart Growth Network aims to encourage the development of smart growth policies across the United States.

Finally, in 1997, the state of Maryland passed the Neighborhood Conservation and Smart Growth Act. After the legislation was passed, Democratic Governor Parris Glendening established an Office of Smart Growth that was housed in the governor's office. It was the first gubernatorial-level "smart growth office" in the nation. Maryland's law is designed to target development in certain areas close to the urban core, and at the same time includes land-preservation strategies to prevent development on the outer edges of the region. Specifically, Maryland's Priority Funding Area program, a central element of the law, allows counties and local jurisdictions to receive funding for public infrastructure, such as public sewer, water, schools, and housing, only if development occurs in designated growth areas and preexisting communities.

The Rural Legacy program, a second key element in the law, establishes a funding stream for buying the development rights of farmland, open space, and environmentally sensitive areas with the explicit goal of preserving farmland and green fields. Over the years, Maryland's smart growth program has won numerous awards and accolades, yet there is still some controversy over the program's ability to prevent sprawl.

According to the Maryland Department of Planning, land consumption by large-lot development is still a problem. The agency found that between 1990 and 2004, the highest rate of land consumption by residential development occurred outside its Priority Funding Areas. Since Maryland's law was passed in 1997, smart growth programs have emerged in other U.S. states. According to a study conducted by the American Planning Association in 2002, one-quarter of all states had strong-to-moderate smart growth policies. These states include Delaware, Florida, Georgia, Maryland, New Jersey, Oregon, Pennsylvania, Rhode Island,

Tennessee, Vermont, Washington, and Wisconsin. There are now examples of smart growth programs in a variety of places.

Examples of Smart Growth

Arizona's Governor Jan Brewer recently established the state's Growth Cabinet. In 2006, this group of 13 state agencies in Arizona came together to consider issues of water and air quality as they developed ways to integrate land use and infrastructure planning across the state. An extensive component of Arizona's smart growth strategy included an extension of the Valley Metro project, a light rail project in the Phoenix metropolitan area. In 2008, the first 20 miles of the light rail started accepting passengers.

In 2001, then Michigan Governor Jennifer Granholm introduced a number of smart growth policies to slow down the rate of land consumption in agricultural and open space areas by suburbanization. Part of the strategy revolved around revitalizing older suburbs and inner cities. Michigan's Cool Cities program aimed to redevelop cities and the Fix It First policy focused on redeveloping existing infrastructure rather than developing anew.

The Illinois state legislature passed the Green Neighborhood Grant Act in 2007, offering financial incentives for the development of more energy-efficient, environmentally sustainable, and pedestrian-friendly communities. The state also offers incentives to developers who create workforce housing and locate housing near major employers. Many of the state-level examples of smart growth initiatives are policy-oriented strategies that offer tax incentives, subsidies, or public investments to encourage development in particular locations and/or of a particular type.

There are literally thousands of individual community-level examples of smart growth initiatives. Each year, the EPA offers a National Award for Smart Growth Achievement to those communities that introduce and implement smart growth strategies in new and innovative ways. The EPA created the National Award for Smart Growth Achievement in 2002. From 2002 to 2013, the agency received 809 applications from 50 states, the District of Columbia, and Puerto Rico.

Examples of the winners include Lancaster, California, for redeveloping its downtown corridor with mixed-use development and housing, and business

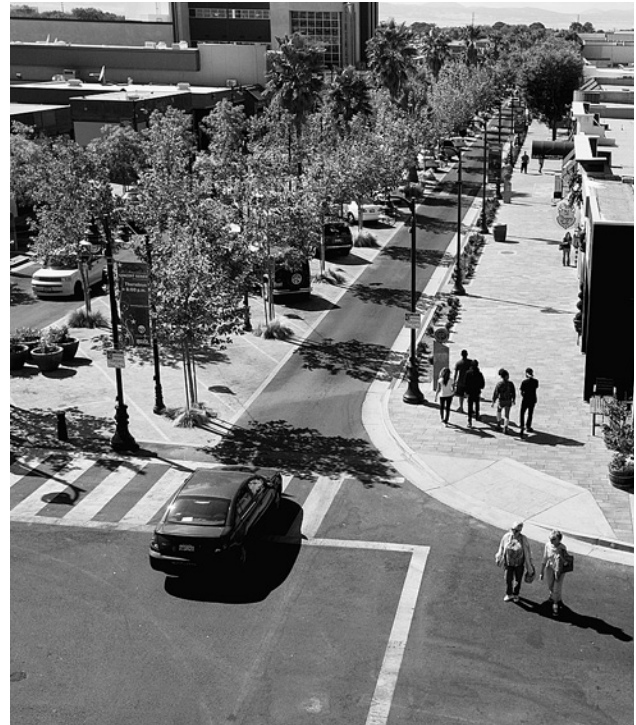
and streetscape redevelopment; Portsmouth, Virginia, for conducting a major overhaul of its land use regulations to become more pedestrian friendly; and San Francisco, California, for developing a \$50 million revolving fund for loans to invest in affordable, transit-oriented housing development. Many of the local-level examples can focus on the design elements associated with smart growth, including the development of more walkable streetscapes, mixed-use developments, and transit-oriented planned communities.

Criticisms of Smart Growth

A study of Maryland's smart growth program in 2009 suggests that it has largely been unsuccessful at preventing sprawl in the state. The researchers state that "[t]here is no evidence after 10 years that [Maryland's Priority Funding Area policy] ha[s] had any effect on development patterns." The researchers found that after Maryland's smart growth legislation passed in 1997, the number of parcels developed outside the Priority Funding Areas increased, an effect the legislation is supposed to prevent.

Other studies of Maryland's law found that although most urban development that happened after the law passed did occur inside Priority Funding Areas, this was the case even before the law. The question therefore remains whether the law had any impact at all on the pattern of urban growth in the state. Some critics argue that part of the difficulty with implementing successful smart growth planning at the state level is that it requires alignment of local goals with state objectives. This is often not the case. Growth management plans are often voluntary at the local level. If local governments do not want to fully embrace smart growth initiatives, then smart growth planning will not happen. Some critics suggest that smart growth is unlikely to be effective as long as local governments maintain exclusive power over local zoning and land use.

In other cases, critics of smart growth believe it increases land values and renders housing more unaffordable. Because smart growth policies limit growth in certain areas, the supply of land for residential development is reduced, causing land values to rise and housing to become more expensive. This, critics argue, has a negative impact on poor and minority families. These critics advocate a more market-based approach where government has less



Lancaster, California, won an award for excellence in smart growth from the U.S. Environmental Protection Agency in 2012 for the redevelopment of its downtown focusing on Lancaster Boulevard, shown here after completion of the project.

involvement in managing where urban development happens.

The Future of Smart Growth

The planning and policy initiatives behind smart growth have in many ways been deepened and expanded to include concerns with issues of sustainability and climate change. Since smart growth first emerged in the 1990s, the conversation about suburban sprawl has focused on how it connects to problems such as the energy crisis and global warming. Attempts to establish links between automobile use and greenhouse gas emissions have energized the debate over urban form and the need for more compact transit-oriented development.

Smart growth has always had a tone of environmentalism; for example, the impact of urban development on the Chesapeake Bay was of importance in the political debate over smart growth legislation in Maryland. But, with jurisdictions seeking ways to achieve emissions-reduction goals, smart growth development is becoming an increasingly viable

policy strategy. Households are concerned about rising energy prices, too, and they are seeking new ways to reduce transportation costs.

Also, and maybe more importantly, demographic shifts mean that there is a potential market for more compact, mixed-use urban-style development. Household sizes are getting smaller, reducing the demand for large single-family housing. All this means that the rationale for implementing smart growth policy is energized and bolstered. The smart growth framework is likely to remain an important element of urban planning as people consider sustainable solutions to future urban growth.

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See Also: Environmental Protection Agency; Jobs–Housing Balance/Spatial Mismatch; Transit-Oriented Development; Transportation Impacts on Land Use; Urban Sprawl Versus Compact Development.

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The Dutch smart highway was designed by Daan Roosegaarde and Heijmans Infrastructure, whose designs were awarded the 2012 Best Future Concept award in the Dutch Design Awards. The designs will be implemented in the Netherlands in phases from 2012 through 2018.

The first stage, adopted in North Brabant in the southern Netherlands, consists of glow-in-the-dark lane markers that charge up with sunlight during daylight hours and glow for up to 10 hours at night, brightly enough to provide a glow along the contours of the road. Used in areas without pedestrians, where further illumination is not needed, this eliminates the need for energy-intensive electric streetlights. Other concepts submitted by Roosegaarde include streetlights powered by the wind of passing cars, which could be used for illuminating street signage.

Future features include dynamic paint, which responds to temperature changes in order to warn drivers of slippery or icy driving conditions by displaying warning signals on the road surface. For example, in the concept design portfolio, freezing temperatures cause a snowflake pattern to become visible on the road surface. A similar warning system triggered by wind conditions is expected to be implemented in 2018.

One of the most talked-about features of the Dutch smart highway is the priority induction lane. Inspired by the third rail of railway systems, which provides electricity to trains capable of drawing from it, the induction lane is a traffic lane reserved for electric vehicles and capable of charging them via magnetic induction as they pass across it. Similar induction methods are already in use to power vehicles elsewhere, including vehicles developed in South Korea by the Korea Advanced Institute of Science and Technology as part of Seoul's efforts to become the world's leading city in green technology design and implementation.

Many of Roosegaarde's innovations are energy conscious, which is a common theme in smart highway discussions. Just as the "smart grid" of electricity delivery infrastructure improves efficiency and shortens repair time to save on energy costs, smart highway designs often focus on both fuel efficiency (as with the induction lane of Roosegaarde's) and the electricity use of roadside infrastructure.

Since the worldwide financial crisis of 2008, streetlight usage has been an area where some local

Smart Highways

Smart highways implement recent technology to provide features that improve driving. A broad category, the "smart highway" has been used to refer to automated highway systems and other intelligent transportation systems, as well as the Netherlands' recent safer highway design.

communities have sought to reduce their expenditures. Jacksonville, Florida, and Highland Park, Michigan, have both turned off substantial numbers of streetlights, or limited their use to certain hours, in an attempt to cut costs.

In addition to Roosegarde's wind-powered streetlight, there is the possibility of using the vibrations of cars to produce electricity (called piezoelectricity) to power lights and other roadside infrastructure. The California Energy Commission has approved a plan to explore the use of piezoelectric materials in this context. Such energy-gathering methods can be used for purposes other than illumination as well, such as automated bridge deicing in response to temperature changes.

In 2012, the Federal Highway Administration approved a grant for electrical engineer Scott Brusaw's proposal to design a solar-powered parking lot. Parking lots can neither make do with the minimal illumination of glow in the dark markers (since by their nature they host significant pedestrian presence), nor do they invite the high speeds necessary to power lights with the wind or pressure of passing traffic. Brusaw's proposal is to provide nighttime lighting using light-emitting diodes (LEDs) powered by solar cells. The use of LEDs improves the energy efficiency and allows for an easily configurable display that could display warnings or other important information. Solar panels could also be used to display advertising in order to defray costs.

Smart highway designs have been developed at the same time that driverless cars, also called self-driving, autonomous, or robotic cars, have become a reality. An area of research interest for decades, driverless cars have seen rapid development in the 21st century, sometimes piggybacking on the development of driver-assistance technologies such as automated parallel parking and adaptive cruise control. While not yet available, or even planned, commercially, driverless cars in the near future could be used both for passenger transport (either by their owners or as a taxi service) and for the delivery of goods. An automated highway system has been proposed in tandem with this eventuality.

In such a system, dedicated roads or road lanes would be used exclusively by driverless cars, which could communicate with one another through systems either required to be included in such cars or provided by the highway itself. Such communication would include information on speed, location, and

destination, giving the highway and/or the cars the ability to manage traffic for maximum efficiency. For instance, a smart intersection like one developed at the University of Texas would use no traffic lights, instead managing driverless traffic by manipulating speeds of the vehicles so that each car making a turn arrives at the intersection and is able to turn immediately, without another car being in its path.

While such communication systems are necessary for driverless cars, they could still be useful for human-operated cars and potentially incorporated on normal roads. Just as adaptive cruise control maintains a target speed under normal circumstances (which itself involves responding to road conditions) but reduces or increases that speed in order to avoid collisions, similar systems could be installed in automobiles to respond to triggers from a smart highway that would adjust speed or suggest a lane change to the driver in order to better manage the highway's traffic.

Traffic Management

A number of traffic jams are caused or worsened by the inability of drivers past the first few cars in the jam to perceive the conditions causing the jam, and so they cannot make anticipatory adjustments such as lane changes or detours. Roadway signs have been used in some areas to convey some amount of information but usually do little more than estimate the delay time and warn of a lane closure.

Smart highways could also manage traffic in response to emergency conditions, including weather events and evacuation routes, spills, and the rerouting of lanes in order to better accommodate emergency response vehicles. Just as systems like EZ-Pass automatically bill tolls to an account as the car equipped with the EZ-Pass rolls through a toll booth lane, a smart highway system can automatically deduct tolls without needing traffic to ever slow down, and could even divide tolls into more discrete increments based on usage, if that suited the needs of the community.

Smart highways could provide map information to vehicles, which could include nearby gas stations, mechanics, accommodations, and emergency assistance, as well as advertisements for businesses, which could help defray the costs of highways while providing more personalized billboard messages.

Of course, smart highways could also be used to monitor traffic violations such as speeding, reckless

driving, and other enforcement measures. Speed limits could also be enforced.

Accident Avoidance and Security

The Department of Transportation believes most car accidents are avoidable; smart highways could assist in avoiding them. Even smart highway signs, which notify drivers of accidents ahead or of stalled cars, would significantly impact both the number of accidents and the severity of the accidents that occur. In particular, the number of large multi-vehicle accidents could be curtailed.

Security applications of smart highways are considerable. Automatic license plate number recognition by digital camera is fairly simple, but if smart highways were widespread, license plates could be replaced or supplemented by symbols intended to be read by digital devices. This could enable automatic ticketing for speeding or other easily identified violations, or alert nearby police about erratic driving and other dangerous conditions that may require a response. Further, such technologies could provide homeland security authorities with information about transportation and transit patterns.

Highways could potentially be built to detect accidents as they occur, summoning help to the scene while also adjusting roadside signage to prevent a pileup. Integration with in-vehicle call systems (such as General Motors' OnStar) could collect information about passenger safety following an accident even before responders arrive. Separately, simple devices such as inductive loops embedded in the road could provide an accurate count of vehicle traffic on a given route to assist in transportation planning.

Smart highway design is supported by the Intelligent Transportation Society (ITS) of America, established in 1991 to advocate the development of smart highways in the interest of greater safety and sustainability. The U.S. group is instrumental in organizing the ITS World Congress, which pursues advocacy at the global scale, as well as maintaining state chapters in each of the 50 U.S. states.

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See Also: Intelligent Transportation Systems; Intelligent Vehicle Highway Systems; Smart Cars; Traffic Engineering; Traffic Laws and Enforcement.

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Smog

The word *smog*, derived from the combination of the words *smoke* and *fog*, came into use in the early 1900s. Smog appears as a light brown blanket of air over heavily populated or industrial areas, although wind may blow smog out into suburban or rural areas. Requiring neither smoke nor fog, smog is a photochemical reaction in which air polluted with hydrocarbons and oxides of nitrogen, particularly from automobile exhaust, interacts with ultraviolet radiation from the sun, creating ozone (O₃). Thus, smog is more prolific in the summertime when temperatures rise and the days are longer. Sulfurous smog, as occurs with the burning of coal or other fossil fuels, increases with dampness.

Environmental Impacts

There are many health and environmental impacts resulting from smog. Negative health effects of smog include eye irritation, asthma, bronchitis, pneumonia, and respiratory distress. When lead exposure, most commonly resulting from resuspension of lead-contaminated soil, is included as a component of smog particulates, increased likelihood of learning disabilities exists. High levels of smog, often signaled by ozone warnings, can cause lung damage in healthy people and create further distress among people with lung and respiratory illnesses. Chronic heart disease and cancer may occur as the result of long-term exposure to high levels of airborne particulates.

In addition to its unpleasant appearance, smog produces many environmental effects. It reduces visibility and its color can be viewable from many miles away. The U.S. Forest Service has documented smog-related damage to trees and moss in



Smog seen across Tiananmen Square in Beijing, China, in 2006. As of 2013, smog levels in some Chinese cities had surpassed safe levels for their inhabitants. While the World Health Organization sets a safe limit for concentrations of $PM_{2.5}$ (the airborne particulates that pose the largest health risk) at 25 micrograms per cubic meter, the level had risen as high as 993 micrograms per cubic meter in Beijing in January 2013. Levels surpassing 600 micrograms per cubic meter were also seen in Shanghai in December 2013.

Pacific Northwest forests. In China, pollution-causing smog is so thick and widespread that it can be viewed from space in the sense that the smog blocks telescope views of the landscape.

Impacts of Industrialization

Particle pollution, also referred to as particulate matter, is a mixture of solids and liquid droplets that form both directly, as a result of pollutants released into the air, and indirectly, as pollutants combine in the atmosphere with other pollutants. Particulate matter that is less than 10 micrometers (PM_{10}) are smaller than the width of a human hair and can enter the lungs creating severe health problems. PM_{10} are coarse dust particles created by crushing and grinding as created through construction. Fine particles, less than 2.5 micrometers ($PM_{2.5}$), are so small that they cannot be seen by the human eye,

but they are detectable with an electron microscope. $PM_{2.5}$ sources include combustion emissions, burning, and some industrial processes.

In China, now an industrialized world leader and economic powerhouse, smog has reached toxic levels. In January 2013 official measures of $PM_{2.5}$, the fine airborne particulates that pose the largest health risk, rose to as high as 993 micrograms per cubic meter in Beijing. Twenty-five micrograms per cubic meter is the limit that is considered humane and still safe according to the World Health Organization (WHO). Air purifiers and face masks are largely unavailable due to skyrocketing demand in the hazy environment. This danger became renowned worldwide when many athletes participating in the 2008 Beijing Olympics trained in Japan rather than in the toxic capital city of China. China is hoping to make enough advances

in controlling pollution to win their bid for the 2022 Winter Olympic Games.

While paling in comparison to the severity of the levels of pollutants found in China, in the United States in 2013, nine of the top 10 smog-producing cities were in the western United States, with Washington D.C./Baltimore being the lone exception. Los Angeles had the highest number of smog/ozone days of the 277 metropolitan areas measured, with a weighted average of 81.8 high-ozone days. Ozone, a colorless, odorless gas consisting principally of nitrogen oxides and volatile organic compounds, is aggravated by carbon monoxide. The weighted average included 205 orange ozone days (unhealthy for people with respiratory illnesses), 10 red ozone days (unhealthy for healthy people), and three purple ozone days (very unhealthy for all). While ozone levels in these top 10 cities is high, the average number of days of high smog alerts decreased from 1996 to 2011, the span of years measured, by two months or more (60 plus days, in some cases).

Inequality

While the negative health impacts of smog do not discriminate, there is inequality in the likelihood of being directly affected by smog. Smog is most dense in heavily concentrated urban areas, where there also tends to be a higher concentration of minority residents and people in poverty. Incidences of asthma and other forms of respiratory distress are elevated in these areas with heightened levels of pollution, and are further exacerbated by stress and exposure to violence. African Americans are three times more likely than are whites to be hospitalized for asthma, with the Centers for Disease Control and Prevention (CDC) reporting that asthma rates for African American children increased 50 percent from 2001 to 2009. Exposure to environmental pollutants, colloquially smog, was listed as a primary contributor to the raging increase.

People who are poor are often unable to control their environment due to a lack of resources such as education and legal access. For example, Altgeld Gardens, an impoverished African American neighborhood on the South Side of Chicago referred to as a minefield of toxic hazards, has a disproportionate number of Chicago's toxic facilities as well as one of the highest cancer rates in the United States. The dilapidated housing project was

built on top of a former landfill, with problems such as approximately 70 percent of residents experiencing respiratory infection intensified by literally tons of pollutants from a nearby sludge plant, a steel mill, a paint company, a huge incinerator, and an 80-foot-high landfill.

Similarly, in Chester, Pennsylvania, whose population is approximately 70 percent African American, five of seven countywide waste facility permits are granted. Chester and Altgeld Gardens became dumping targets not specifically because the communities were predominantly African American but rather because community members have neither the financial means nor the political know-how to stop companies from siting facilities there.

Reducing Smog

There are a number of ways that people can work individually and collectively to reduce smog:

- *Drive less:* Trucks and automobiles produce a significant portion of smog. In 2001, drivers in Los Angeles contributed an average of 65 pounds of smog per person per year. The worst offenders, though, were Louisville, Kentucky, and Oklahoma City, Oklahoma, each contributing an average of 137 pounds of smog per person that year. While still very polluted with smog, restrictive state emissions standards contributed to Los Angeles' relatively low truck and automobile emissions.
- *Use alternate transportation:* By carpooling, walking, or biking, people can prevent some of the automobiles from polluting the environment and contributing to smog. When buses and trains are full, these modes of transportation produce fewer pollutants than do individuals driving in cars.
- *Stop idling:* When automobile engines idle for at least 30 seconds, more fuel is burned than if the engine were turned off and restarted. Turning off the engine wastes less fuel and gas money, as well as reducing smog.
- *Be aware:* Many local news organizations post warnings when smog/ozone is at a dangerous level for humans. People can also sign up for smog alerts from local or

regional associations, such as the Georgia Department of Transportation's Clean Air Campaign and the Southwest Ohio Air Quality Agency.

While smog is an ugly reality worldwide, there is evidence that individual and collective efforts are helping alleviate the levels of pollutants in the air. Through continued efforts, smog could become an infrequent occurrence in the future.

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See Also: Automobile Emissions Lead Pollution; Mobile Emissions; Particulate Matter; Vehicle Fleet Emissions.

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Social Equity and Discrimination in Transportation

Discrimination in transportation was rarely explicitly considered in transportation policy, at least in the United States, until the mid-1990s. Historians have noted that urban highway construction projects disproportionately affected low-income and minority communities beginning in the mid-1950s and only tailed off as new urban highway construction was curtailed during the 1970s. Despite this history, transportation professionals have often viewed their profession as one that improves the transportation options of the public without regard to race or social class. This understanding was challenged in the early 1990s when the frame of environmental justice was applied to transportation planning.

Legislative Background in the United States

Despite the history of urban highway construction disproportionately impacting low-income neighborhoods (sometimes explicitly in conjunction with slum clearance projects), much commentary about transportation—particularly highway projects or other road improvements—often asserts that public transport benefits everybody equally. This understanding has been increasingly challenged from a social equity perspective and arguably is no longer the majority perspective among transportation planners and government officials. This change can be at least in part attributed to the rise of the environmental justice perspective in the transportation sector.

The environmental justice movement investigates issues of equity and whether minority and low-income neighborhoods are bearing disproportionate environmental risk. The early environmental justice movement largely focused on toxic waste dumps and industrial pollutants affecting minority neighborhoods, but this frame was expanded in the 1990s to include the effects of transportation projects on minority and low-income communities, such as highway construction projects through inner-city neighborhoods or Native American lands, as documented by R. Bullard and G. Johnson in 1997. Among issues that led to several civil

rights court cases was whether transit providers were favoring rail investments that served predominantly white, middle-class commuters at the expense of low-income and minority bus patrons.

One significant action took place in 1994 when the Los Angeles Bus Riders Union and the Labor/Community Strategy Center sued the Los Angeles Metropolitan Transit Authority (MTA), alleging that the MTA's fare policies and rail construction programs disproportionately affected local transit dependents. The plaintiffs argued that the MTA was systematically undermining bus service, which served minority and low-income riders, to fund construction of its subway and light rail system, which had been designed to service primarily higher-income areas and tourist destinations. The parties eventually reached a settlement in which the MTA agreed to improve local bus service. The success of the plaintiffs' lawsuit led to a much broader investigation of the distribution of benefits and costs of various urban and regional transportation plans.

U.S. federal surface transportation law, particularly the then-current Intermodal Surface Transportation Efficiency Act (ISTEA), specifically called for metropolitan planning organizations to develop regional plans that were in compliance with Title VI of the Civil Rights Act. The act forbids transportation agencies from discriminating on the bases of race, color, or national origin. There was no federal guidance to direct planners on how to assess environmental justice impacts on low-income and minority populations, although a federal response was forthcoming.

President Bill Clinton signed Executive Order (EO) 12898 in 1994 calling on all federal agencies to specifically analyze how their decisions were affecting minority and low-income populations and to try to avoid disproportionate adverse effects on these groups. This EO can be considered the first step toward mainstreaming the concept of environmental justice into federal decision-making processes. Interim guidance to evaluate (and avoid) disproportionate adverse effects was provided by the Federal Highway Administration, Federal Transit Administration (FTA), and the Environmental Protection Agency (EPA) between 1995 and 1998, with the first stand-alone FTA circular on environmental justice published in August 2012 (FTA C 4703.1).

Although such findings were relatively uncommon, in 1999 the EPA found two regional planning

agencies, the Northwestern Indiana Regional Planning Commission and the Charlotte Area Transit System, to be out of compliance with EO 12898. The agencies were issued corrective actions and required to improve their examination of environmental justice in their long-range planning processes. In consequence, regional planning agencies expanded the types of transportation outcomes they measured and paid more attention to how costs and benefits were distributed across their regions and whether there were clear patterns that would indicate low-income residents or minority neighborhoods were uniquely disadvantaged. Nonetheless, it is still the case that within the United States, there is a wide variation in terms of how each planning agency measures equity and environmental justice—both in the types of measures examined and the rigor of the analysis. While planning agencies outside the United States have begun to consider issues of equity while developing plans, the administrative requirements are generally higher in the United States than elsewhere.

Analysis of Impacts

One difficulty in generating such guidance is that there are multiple definitions of social equity. Some draw more on horizontal equity, asserting that people should generally be treated equally, relatively to their ability to pay. In particular, user-pays systems assume that users of a transportation system and/or those who benefit from a particular facility should be primarily responsible for paying for the system. Some theorists contend that user-pays is hard to achieve in transportation precisely because there are so many positive and negative externalities, even across modes. Another standard is proportional equity, which asserts that the wealthy should pay more than the poor because they are better able to bear the burden of financing transportation systems and government functions more generally. Progressive taxes are based on the concept of proportional equity.

The FTA does not clearly ground its guidance in any particular equity framework, though its emphasis is on ensuring that disadvantaged groups are not clearly adversely impacted compared to the rest of the population, suggesting these rules are primarily based on maintaining horizontal equity. The FTA recommends using geographic units of analysis, so an area may be treated for the

purposes of analysis as a low-income or minority neighborhood. The benefits and social costs of carrying out a particular transportation plan or building transportation infrastructure are then assessed at these various neighborhood levels. A project may proceed if the disadvantaged neighborhood does not face disproportionate adverse impacts relative to non-disadvantaged neighborhoods (although negative impacts can also be balanced against strong positive benefits in deciding on the merits of the project).

There are clear limitations with this approach as it examines impacts on an aggregate basis, ignoring social equity considerations of individual low-income persons living in a neighborhood filled with middle-class households. Furthermore, as Paul Mohai (1995, 2008) and other researchers have pointed out, drawing different geographic boundaries and changing the reference categories can lead to different findings of adverse impact. Some activists believe that the institutionalization of environmental justice by the government has turned this into a technical issue driven by technocrats that shuts out neighborhood advocates. Without minimizing the limitations of the proposed approach, these analyses are focused on long-term impacts of transportation decision making; a more aggregate approach is acceptable and perhaps may be the only feasible approach for undertaking such analyses. The fact that the federal government takes social equity issues into consideration in transportation planning is a considerable and perhaps remarkable shift away from the planning approach of the 1950s and 1960s.

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See Also: Civil Rights and Transportation; Environmental Justice; Executive Order 12898; Federal Transportation Policy; Spatial Equity Analysis; Transportation and the Disadvantaged; Travel Patterns by Income; Travel Patterns by Race/Ethnicity.

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Space Travel, Commercial

Humankind truly entered the Space Age in 1957 when the Soviet Union launched a capsule called *Sputnik* into Earth orbit. The size of a basketball, the silvery *Sputnik* did little but emit a steady tracking beep. Nevertheless, it ignited the Space Race between the United States and the Soviet Union that broke open the new realms of space.

The two countries vied for a number of firsts in space: first object in space (*Sputnik*); first man in space (Yuri Gagarin, Soviet); first spacewalk (Alexei Leonov, Soviet); first multivehicle rendezvous and docking (Gemini program, United States); first manned lunar orbit (United States, *Apollo 8*), and first lunar landing (United States, *Apollo 11*).

One can argue that the missions of the Space Race were in fact commercial, for the National Aeronautics and Space Administration (NASA)

hired out the manufacture of essential components to private industries. Lockheed, for example, made the Apollo spacecraft; Grumman made the lunar module (LM) for manned moon missions. However, in the purest sense, they were not commercial. NASA and the Soviet space agency drew astronauts and cosmonauts from their country's military branches. Most American astronauts had been fighter pilots; many were air aces from the Korean War. Not until Harrison Schmidt, a geologist, went to the moon in *Apollo 17* in 1972, did a true civilian go into space.

Paid Space Passengers or Space Tourists

U.S. space shuttle missions, active from 1981 to 2011, brought the first chance for something like real commercial spaceflight. First, NASA began allowing members of the European Space Agency (ESA) on flights, and space contractor McDonnell Douglas paid for one of its engineers to fly on a shuttle. Then, NASA accepted congressional advocates of manned spaceflight to ride along on shuttle missions. Senator Jake Garn (R-Utah) and Representative Bill Nelson (D-Florida) made flights in 1985 and 1986, respectively. The civilians went aloft as "mission specialists," meaning they received limited training in only certain fields, nothing like the pilot training of regular astronauts. In the cases of the flying congressmen, their mission was publicity.

NASA attempted to validate its civilians in space program with the Teacher in Space effort. Elementary school teacher Christa McAuliffe was to present lessons from space to students on Earth via satellite links. McAuliffe and her six crewmates died, however, in the *Challenger* explosion in January 1986. NASA was about to resurrect the civilians-in-space program in 2003 by sending a journalist on a shuttle flight. It scuttled any further civilian plans when the *Columbia* broke up on reentry on February 1, 2003, killing its crew.

Meanwhile, the Russian Federal Space Agency and some U.S.-based private companies, such as Space Adventures, began facilitating passenger flights to the old Soviet MIR space station, and later the International Space Station (ISS). Most of those passengers rode on Russian Soyuz spacecraft. After all, American space shuttle missions ended in 2011, so any Americans in space are also getting there via the Russian Soyuz fleet, with NASA paying Russia

for the rides. In April 2013, NASA signed a deal for the Russian Federal Space Agency to take six Americans into space aboard Soyuz crafts between 2013 and 2017. NASA will pay an incredible \$70 million per ride.

Private Cargo, Public Engines

Early in the days of spaceflight, the U.S. Congress passed and President John F. Kennedy signed the U.S. Communications Satellite Act of 1962. It allowed NASA rockets to place privately owned communications satellites into orbit. While the act generated debate, it was little more than what the U.S. government had done to facilitate railroad travel across the American West. As early as the 1850s, the federal government acknowledged that a transcontinental railroad was necessary to link the eastern United States with western states. It also acknowledged that private railroads should do the work, but a project of that magnitude required resources and capital that only the federal government could muster. When Congress passed the Transcontinental Railroad Bill in 1862, the government agreed to subsidize railroads with grants of land, rights-of-way, and cash.

A century later, the Communications Satellite Act did much the same thing. Private companies would fund the satellites themselves, but the federal government would use its rockets and growing skill at orbital mechanics to place the satellites in the proper position to bounce, or relay, telephone and television signals. The Bell Telephone system funded the first private launch under the program. Bell Labs built *Telstar 1* and *Telstar 2*, which U.S. Delta rockets boosted into orbit in 1962 and 1963, respectively. (The satellites so caught the public fancy that an instrumental pop song, simply called "Telstar," climbed up the charts.) Long out of use, the satellites remain in orbit.

The United States, the Soviet Union, and later the Russian Federation continued to place private satellites in orbit in the 1960s and 1970s. In 1980, the European Space Agency (ESA) got into the private space cargo field with its Ariane rockets.

Encouraging Commerce and Privatization

In February 1988, President Ronald Reagan signed the Commercial Space Launch Act. It pledged the United States to legislation and policies that would make space available to private companies. It said

the United States would begin seeking launch opportunities from private companies, thus encouraging the private sector to develop its own boosters.

As further incentive, Reagan put the private sector, and to some degree, the world, on notice that the United States was not going to keep its reusable space transport, the shuttle, in service indefinitely. Though the shuttles remained in service until 2011, NASA had planned to decommission them as early as 2005.

In 1990, President George H.W. Bush signed the Launch Services Purchase Act. It effectively took the federal space agency out of the satellite launching business, putting the burden of continued satellite placement squarely on the shoulders of private industry.

In 2005, President George W. Bush announced the Constellation program, which would return Americans to the moon in phased operations. Constellation would involve Ares boosters (with detachable, reusable primary boosters, technology from the shuttle program) and Orion crew and service modules that looked much like the central components of the Apollo vehicles. NASA designers, in fact, called Orion “Apollo on steroids.” Bush said Constellation would re-establish American presence in space and lay the groundwork for further explorations, even to Mars.

In reality, it was simply an attempt by Bush to recapture the magic of Apollo and rescue NASA from the doldrums of the quarter-century-old space shuttle program. NASA, however, could never settle on a feasible cost estimate for Constellation.

When Barack Obama became the U.S. president in 2009, he authorized a Human Spaceflight Plans Committee (later known as the Augustine Committee) to review the Constellation program. The committee reported that Constellation was wildly behind schedule and over budget. Obama cancelled it, much to the chagrin of manned spaceflight advocates, including Neil Armstrong, the first man to walk on the moon.

Obama said he was not against the program in its entirety, but he wanted a program with more imagination (such as going directly to Mars or exploring asteroids) and did not want to waste time boosting astronauts to space stations in low-Earth orbit, which was a foundation of Constellation. Thus, Obama continued the general trend in U.S. spaceflight of letting NASA handle the dangerous edge of new space

exploration and handing over well-established space practices to the private sector.

Boom in Commercial Space Companies

In 2002, entrepreneur Elon Musk founded the space cargo company SpaceX. In 2006, it was one of two companies to which NASA awarded a Commercial Orbital Transportation Service contract to subsidize a private venture to ferry cargo to the International Space Station.

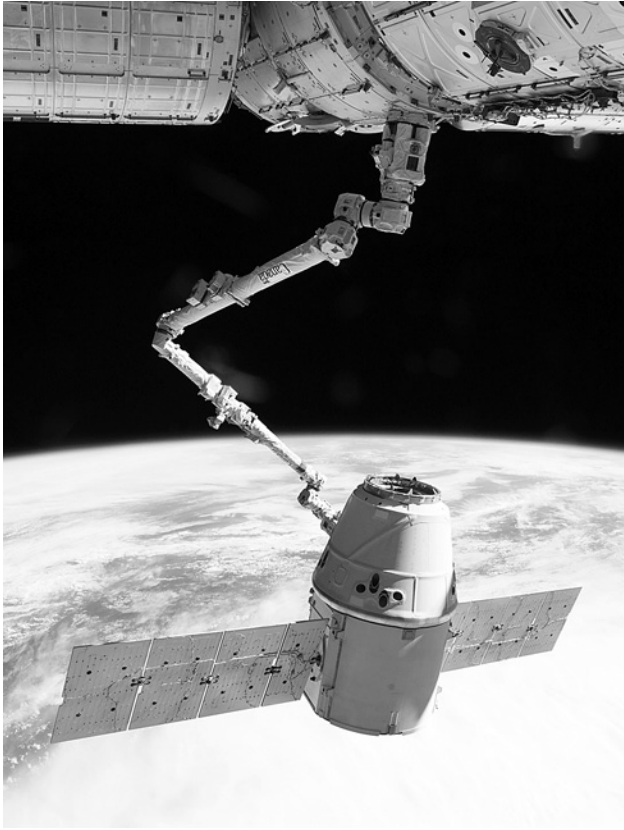
In 2012, SpaceX’s unmanned Dragon cargo craft successfully docked with the ISS and delivered cargo. The mission proved that private enterprise could enter orbit and rendezvous and dock with another spacecraft. NASA spent many Gemini flights in the mid-1960s learning those maneuvers. SpaceX Dragon proved the validity of NASA passing on its learned skills to the private sector.

As of 2013, 25 private international companies were developing space cargo and transport businesses; four were planning space stations; 16 were planning launch vehicles; 24 were planning moon-landing missions (one of which was named Golden Spike, a term that harkens back to the public/private character of the first transcontinental railroad); five were planning to mine the moon or near-Earth asteroids; and one, Mars One, was fund-raising and taking applications for married couples to go on a long-term mission to Mars. Many of those burgeoning companies were members of the Commercial Spaceflight Federation. The federation is an umbrella organization designed to facilitate interface with NASA or other space agencies.

X-Prize

As with anything commercial, money drives the goal. Exploration, new technologies, and medical advances may all be ultimate goals, as well, but financial incentives often get things moving. Such is the thinking behind the X-Prize, organized and funded (with partners) by the Exploration Prize Group, founded in 1995.

The first X-Prize incentive, \$10 million in cooperation with Ansari, would go to the team that could build and fly a craft with three people to a height of 60 miles (100 kilometers). They also had to accomplish the feat twice in two weeks. The winners were a team from Scaled Composites headed by Burt Rutan, a famed aerospace engineer whose Voyager long-distance aircraft flew around the world in nine



SpaceX's Dragon cargo craft docking with the International Space Station on March 3, 2013. It successfully delivered its cargo and stayed for three weeks. As of 2013, 25 private companies were developing space cargo and transport businesses.

days in 1986 without stopping or refueling. Rutan's SpaceShipOne claimed the Ansari prize in 2004. The successful mission helped set off the rush for private spaceflight achievements.

In 2009, Armadillo Aerospace and Masten Space Systems claimed \$2 million in a Northrop Grumman lunar lander X-Prize challenge. The mission was to build a rocket-powered vertical takeoff and landing (VTOL) craft that could demonstrate, repeatedly, on Earth the same type of landings and lift offs that a lunar mission would require.

As of 2013, Google had partnered with X-Prize to offer a \$30 million prize (the largest yet offered) to a team that could successfully land a robot on the moon, have it travel at least 500 feet, and then successfully transmit images and data back to Earth. NASA sweetened the pot, offering another \$30 million in contracts to the team if it accomplished a list of NASA-prescribed scientific objectives.

Manned Private Spaceflight

With the high price of Russian space tickets for American astronauts, and no small amount of glory that will come to whoever gets U.S. manned spaceflight moving again, private manned missions will not long lag behind unmanned flights.

On April 29, 2013, Virgin Galactic's SpaceShipTwo (also designed by Rutan's Scaled Composites) successfully completed an engine test that boosted the craft. SpaceShipTwo was hauled aloft by a mother ship, WhiteKnightTwo, which let it go at 48,000 feet. SpaceShipTwo then successfully finished its climb to 55,000 feet and achieved a speed of Mach 1.2. It then returned to a base on the floor of the Mojave Desert.

Virgin Galactic founder Richard Branson anticipated passenger flights on ships similar to SpaceShipTwo would begin after more rounds of engine testing in 2013 and 2014. Prices for suborbital trips would start around \$250,000 each, and then begin to drop after Virgin Galactic carried 1,000 passengers. SpaceShipTwo is still something of a tourist draw; it is not expected to do much for exploration or science. Nevertheless, it should prove that private carriers can safely ferry passengers without spaceflight training back and forth from space.

Others, such as Mars One, hope to prove the viability of private space-faring companies in true exploration. In April 2013, Mars One began taking applications for people to go on the first mission. Spaceflight training and experience were not necessary. In two weeks' time, Mars One had 78,000 applicants competing for four mission slots. Mars One hopes to land those four on Mars in 2023, then land others over two years as the basis of a permanent Martian colony.

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See Also: Aeronautics; Aeronautical Decision Making; Emerging Technologies; Telecommuting and Telecommunications.

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Spatial Equity Analysis

Spatial equity analysis examines the fair allocation of public resources within units of government at the local, regional, and national levels. Distribution of public investments is considered fair when it is needs based irrespective of the demographic and socioeconomic profiles of each community.

Some of these distributions, of course, go to transportation investments, to the extent that historic developments in each locale have resulted in the separation of different land uses. Thus, transportation funds are needed for travel for a variety of reasons, such as commuting from and to work, traveling from and to a school, making shopping and business trips, visiting a doctor, and so forth.

It is relevant to examine, for example, whether a particular transit investment would assist the employability status of central-city minority workers facing housing segregation in the face of the suburbanization of entry-level jobs in the manufacturing or services sectors of the economy. In this case, the analysis may examine whether the minority community's welfare is improved with respect to job accessibility, commuting duration, and earnings.

A careful analysis could also determine, in this context, that longer commuting distances among workers of a particular racial group were not the result of housing segregation but rather a result of selective migration among members of that racial

group, who may have chosen to live farther away from jobs as a trade-off for better access to quality education for their children.

Another possible investigation may be concerned with how minorities' welfare varies geographically, or by gender, age, race and ethnicity, and education attainment. For example, one question could be whether employment security of female workers from minority communities is the effect of job retention (i.e., tenure with the same employer) or of employment retention (i.e., keeping jobs but with different employers), possibly with a trend toward upward mobility.

The next question might be, does vehicle access increase employment retention, or, more importantly, how many job opportunities can be accessed by a private vehicle (versus public transit systems) within reasonable travel time? Finally, do female minorities with a high school diploma, when given the appropriate accessibility and location opportunities, enjoy increased job retention?

A Case Study Example

In a planning study of the Chicago metropolitan area, authors examined in depth the transportation component of the welfare-to-work problem and provided strong support for the spatial mismatch hypothesis facing welfare clients and the unemployed. The study found the following:

- The spatial distribution of welfare clients and entry-level jobs imposed challenges for transit service providers because clients and jobs were dispersed throughout the metropolitan area.
- Welfare clients were likely to face significant difficulties in accessing jobs because of long distances and their need to access jobs through heavily congested urban areas, which resulted in extremely high door-to-door travel times between residential origins and job destinations, whether trips were by private automobile or existing transit services.
- There were wide variations in the travel times to job destinations from different neighborhoods. Some neighborhoods were relatively close to a large number of entry-level jobs, while others were rather far, and competition for the few

conveniently located jobs among many welfare clients made the transportation challenge much greater.

- Tremendous variations existed within the Chicago metropolitan area regarding spatial competition for jobs.
- Physical proximity to a job did not necessarily imply an increased opportunity for employment (i.e., if there are a large number of individuals in close proximity competing for the same job, there may be little benefit from physical proximity). In fact, the level of job accessibility in the Chicago central business district (at the time, close to 13 percent of all entry-level job openings) for welfare clients was lower than in many other areas in the region.
- Job stability in terms of full-time or part-time employment, as well as the length of job retention, appeared to be related to access to private transportation.

Transportation and Environmental Justice

Federal mandates dictate that land use and transportation analyses in state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) consider the three core principles of environmental justice: (1) to avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects, on minority populations and low-income populations; (2) to ensure the full and fair participation by all potentially affected communities in the transportation decision-making process; and (3) to prevent the denial of, reduction in, or significant delay in the receipt of benefits by minority and low-income populations.

Spatial Mismatch Research

The main question for spatial mismatch research is whether the suburbanization of jobs and the serious limitation on black residential choice have acted together to create a surplus of workers relative to the number of available jobs within inner-city neighborhoods. Empirical research has sought to identify factors that contribute toward such disparities.

Such research has verified the continuation, albeit at a slower pace, of the suburbanization of

population and jobs since World War II; the changing distributions of job skills and worker skills; the segmentation of urban labor markets; the inability of black residents to follow the suburbanization of employment; the over-representation of blacks in central cities; the commuting disparities between blacks and whites; the poor access to job opportunities for blacks; the concentration of unemployment, low income, and poverty in central cities; and the residential inertia of blacks in poor areas. In view of the empirical research, theoretical developments have proposed several underlying mechanisms for such spatial disparities:

- The efficiency of job search may decrease with distance to jobs. Workers may obtain less information about distant job opportunities while firms resort to local recruiting methods, such as ads in local newspapers or “help wanted” signs not seen by distant workers.
- Incentives may be too low for workers residing far away from jobs to search intensively. For instance, when housing prices are very low at a distance from jobs, unemployed workers may feel less pressure to find a job in order to pay their rent. Alternatively, if the search costs are much higher for distant workers, then they may be discouraged and search less intensively.
- Workers may refuse jobs that involve particularly long commutes because commuting to that job would be too costly in view of the proposed wage. They may instead prefer to search for job opportunities in the vicinity of their neighborhood. As a result, workers may restrict their spatial search horizon.
- Inadequate transportation can exacerbate both search and commuting costs, amplifying the issues just listed.
- Employers in distant or suburban areas may discriminate against residentially segregated workers because of the stigma or prejudice associated with their residential location. Employers may hold the view that, on average, inner city residents are less productive or more likely to be criminal (statistical discrimination).

- Employers may refuse to hire or may pay lower wages to distant workers because commuting long distances makes them less productive (for example, they are more tired or more likely to be absent).
- Employers may believe their white local customers are unwilling to have contact with minority worker, and thus discriminate against minority workers (customer discrimination).

Job Access and Reverse Commute Programs

Employment transportation services were developed to provide access to jobs for people who otherwise would have few transportation options, either because public transportation is not available to their jobs or employment-supportive destinations (for example, day care, schools, job training, job search, etc.) or because they cannot afford to own and operate a private vehicle.

Employment transportation services include traditional fixed-route buses or demand-responsive services operated by local transit agencies; rideshare programs, shuttles, or charter services provided by nonprofit organizations, employers, or employment agencies; information services and mobility brokers that link information on jobs with transportation to those jobs; and car programs that fund ownership and use of private vehicles by low-income workers.

Employment transportation services provide valuable services to users. The services are being appropriately targeted and the individuals who use them are greatly dependent on them. Although program costs are high, benefits to the users are high, as well, and are likely to persist over time.

Empirical analysis has shown that it is not likely that many users will stay in the transit system over the long term, but that the temporary lift that these services provide is likely to make a significant difference in the users' lives and their work. Moreover, nonusers and society in general benefit because of potential alternative uses of tax dollars and avoidance of societal costs of private automobiles that users might otherwise have taken.

The negative impacts on local labor markets are likely to cancel some of these nonuser and societal benefits, but, because these negative impacts are dependent on local unemployment rates, the nonuser benefits from these services are ultimately likely to depend on economic cycles.

Accessibility Measures

The development of accessibility measures is important because it relates directly to the assessment of labor markets' accessibility, a central issue in spatial-equity analysis. In this context, the concept of accessibility has received numerous operational definitions in order to derive various measures and indicators, including (1) accessibility measures as a function of the transportation available to individuals, the temporal and spatial distribution of activities, and the social and economic roles of individuals that determine when, where, and for how long they must pursue different activities; and (2) accessibility measures to evaluate the availability and quality of basic services and alternative transportation modes at the neighborhood level. These accessibility measures represent how easy or difficult it is to reach needed or desired destinations, depending on where they are located and how those locations are served by a transportation system.

In addition, three types of accessibility measures have been used in practice:

1. The simplest type to operationalize consists of cumulative accessibility measures. These measures count the number of opportunities reached within a given distance, and give an indicator of the choices available to residents.
2. Gravity-based measures weight the amount of activity at different destinations by a cost function and the available opportunities in other destinations.
3. The final type derives accessibility from random-utility theory.

Overall, accessibility indicators used in spatial equity analysis are multidimensional in nature, using information from the transportation sector (for example, origins and destinations of trips, travel times, and costs), housing (for example, location of low-income people and affordable housing, crime rates, etc.), and economic development (for example, location of entry-level jobs, day-care centers, etc.) as input. Using such core multisector data, composite indicators and indices can be derived (for example, accessibility to day care, hospitals, jobs, one-stop centers, schools, and affordable housing locations; indices of transportation barriers

for low-income populations; neighborhood quality indices; and indices for job growth and unemployment.). In this regard, the accessibility problem can be frequently cast within the general framework of multiple-criteria decision-making methods.

Data Issues

Data used in spatial equity analysis are collected for different administrative purposes in the public sector (for example, to formulate policies and programs, to allocate government funds, and for business decisions in the private sector of the economy). Such data are usually available for analysis at different geographic scales (for example, census tract, ZIP code, county, etc.) and temporal scales (for example, different times of day, days of the week, etc.), thereby requiring careful statistical handling to alleviate various inconsistencies and error propagation. More spatio-temporal statistical issues emerge when aggregated data are analyzed together with individual personal or household data from surveys in multilevel analysis.

There are instances in spatial equity analysis where the linking of separate databases developed independently of one another becomes critical. In such cases, there are several data quality control criteria for the integrated database that should be satisfied before the analysis can proceed:

1. Does the database include all the attributes required?
2. Do key variables have values?
3. Are the data spatially and temporally consistent?
4. Does the integrated database add value above and beyond its individual database components?
5. Have the data been updated?
6. How accurate are the data elements?
7. Is there an adequate documentation of the data and the metadata?
8. Are the data easily accessible and unrestricted for use with standard equipment and software?

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See Also: Economic Development; Employment Location; Job Access and Reverse Commuting Program;

Jobs–Housing Balance/Spatial Mismatch; Social Equity and Discrimination in Transportation; Transportation and the Disadvantaged.

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Speed Laws and Enforcement

Speed limits are the most common method for managing traffic speed. The current U.S. framework for setting speed limits was developed in the 1920s and 1930s. Speed limits in the United States have traditionally been the responsibility of individual states. State statutes specify speed limits that generally apply to different road types or geographic areas. In the mid-1970s, however, Congress established the National Maximum Speed Limit by withholding highway funds from states that maintained speed limits greater than the 55 miles per hour (mph). The requirement was loosened for rural interstates in 1987 and repealed in 1995. As of today, 35 states have speed limits of 70 mph or higher on some portion of their roadway systems.

In many states, the maximum speed limit that state or local authorities can establish depends on whether the road is a rural or urban interstate, a non-interstate limited-access highway, or another type of road. (Limited-access highways are multiple-lane roads with restricted access via exit and entrance ramps, rather than intersections.) The limited-access highways that make up the national interstate highway system are divided into urban and rural sections, based on population density figures from the U.S. Census Bureau.

State laws set maximum speed limits for each type of road and land use (urban or rural). Legal maximum speed limits also can be established for special situations such as school zones. The posted speed limit for a particular road or section of a road can be below the maximum speed limit allowed, however, if the local or state agency in charge of the road decides a lower limit is warranted. In this case, the state and most local governments have the authority to set speed limits on the basis of an engineering study. These studies usually take into consideration such factors as operating speeds of free-flowing vehicles, crash experience, roadside development, roadway geometry, and parking and pedestrian activity levels before concluding at what speed the posted limit should be set.

As of 2010, most states have increased the maximum posted speed limit above 55 mph for passenger vehicles, trucks, or both. Currently, only three states and the District of Columbia have maximum posted speed limits of 55 mph or lower for cars. One state has established a maximum posted speed limit of 80 mph, 11 states have established maximum posted speed limits of 75 mph, and another 19 have established maximum posted speed limits of 70 mph.

Driver Attitudes

A survey was conducted in 1998 for the U.S. Department of Transportation's National Highway Traffic Safety Administration (after the repeal of the 55 mph limit) on speeding and other unsafe driving behaviors. Some of the findings, not surprisingly, were as follows: there is an inverse relationship between the tendency to pass and age; three drivers in five (60 percent) felt that they often got impatient with slower drivers; and one driver in three (33 percent) said that they "try to get where I am going as fast as I can."

Approximately half of all the drivers in the study reported keeping up with faster traffic, and almost one-third reported being more likely to pass other drivers than to be passed. Both of these driving behaviors decreased with age. In general, positive feelings toward speeding decreased with age. However, agreement with the statement "I worry a lot about having a crash" also decreased with age. Drivers said that the major factors in determining the speed at which they drive were weather conditions, the posted speed limit, and type of road. A large

proportion of drivers felt it was safe to speed in certain situations (not in areas where children, playgrounds, or schools were located). Yet, three drivers in 10 felt speeding was a factor in at least 75 percent of fatal crashes, and two-thirds felt speeding was involved in at least 50 percent of all fatal crashes.

Speed Laws

Most U.S. states have adopted speeding laws that are aligned with the National Highway Traffic Safety Administration's (NHTSA) guidelines and regulations. The following are explanations for some of these:

- *Basic speed rule:* This rule requires vehicle operators to drive at a speed that is reasonable and prudent. As a corollary to this rule, state laws usually provide that every person shall drive at a safe and appropriate speed when special hazards exist with respect to pedestrians or other traffic or by reason of weather or highway conditions.
- *Minimum speed rule:* This rule prohibits a person from operating a motor vehicle at such a slow speed as to impede the normal and reasonable movement of traffic, unless when reduced speed is necessary for safe operation or compliance with law.
- *Racing on the highway:* This is usually defined as driving any vehicle in any race, speed competition or contest, drag race or acceleration contest, test of physical endurance, exhibition of speed or acceleration, or for the purpose of making a speed record.
- *Reckless driving:* This is generally defined as driving any vehicle in willful or wanton disregard for the safety of persons or property. (Speed is not necessarily a factor in this offense.)
- *Posted (maximum) speed limit:* State laws may allow authorities to specify different speed limits on all or selected highways (or portions thereof) either for various times of the day or for various types of vehicles.
- *Automated speed enforcement:* A number of states authorize the use of imaging technology by law enforcement to determine if a violation of the speed law has occurred. Legislative provisions vary widely regarding this issue, state to state.

- *Commercial motor vehicle (CMV) operators:* Generally among the states, a commercial motor vehicle is defined as a vehicle designed to carry passengers or property and has a gross vehicle weight of 26,000 pounds or more, is designed to transport 16 or more persons, or is transporting hazardous materials that require such vehicle be placarded in accordance with state or federal laws.

Highway Accident Data

According to the Insurance Institute for Highway Safety (IIHS) and the Highway Loss Data Institute, in 2011 a total of 9,944 deaths, or nearly one-third of all motor vehicle fatalities in the United States, occurred in speed-related crashes. Speed has a major impact on the number of crashes and injury severity, because it influences the risk of crashes and crash injuries in three basic ways: (1) it increases the distance a vehicle travels from the time a driver detects an emergency to the time the driver reacts, (2) it increases the distance needed to stop a vehicle once the driver starts to brake, and (3) it increases the crash energy exponentially. For example, when impact speed increases from 40 to 60 mph (a 50 percent increase), the energy that needs to be managed increases by 125 percent.

In a high-speed crash, a passenger vehicle is subjected to forces so severe that the vehicle structure cannot withstand the force of the crash. As crash speeds get very high, restraint systems such as airbags and safety belts cannot keep the forces on occupants below severe injury levels. There are limits to the amount of crash energy that can be managed by even the most recently designed vehicles—even with restraint systems and roadway hardware such as barriers and airbags. The higher the speed, the higher the likelihood that these limits will be exceeded in crashes.

The Highway Loss Data Institute studies and other research show that deaths on rural interstates increased 25 to 30 percent when states began to raise speed limits from 55 to 65 mph in 1987. In 1989, about two-thirds of this increase, or 400 deaths, was attributed to increased speed, and the rest to increased travel. A 1999 institute study of the effects of the 1995 repeal of the National Maximum Speed Limit indicated this trend had continued. The institute estimated a 15 percent increase

in fatalities on interstates and freeways in 24 states that raised speed limits.

A 2002 study also evaluated the effects of increasing rural interstate speed limits from 65 mph to either 70 or 75 mph. States that increased speed limits to 75 mph experienced 38 percent more deaths per million vehicle miles traveled than expected, an estimated 780 more deaths. States that increased speed limits to 70 mph experienced a 35 percent increase, resulting in approximately 1,100 more deaths. And, a 2009 study examining the long-term effects of the 1995 repeal of the national speed limit found a 3 percent increase in road fatalities attributable to higher speed limits on all road types, with the highest increase of 9 percent on rural interstates. It was estimated that 12,545 deaths were attributed to increases in speed limits across the United States between 1995 and 2005.

Although there is no definitive research showing crash effects associated with posting lower speed limits for large trucks, many safety experts favor differential limits because large trucks require much longer distances than cars to stop. Lower speed limits for trucks make stopping distances of trucks closer to those of lighter vehicles. Slower truck speeds also allow passenger vehicle drivers to pass trucks more easily.

The Insurance Institute for Highway Safety (IIHS) published research in 1991 that found that lower speed limits for trucks on 65 mph highways reduced the proportion of those traveling faster than 70 mph without increasing variation among vehicle speeds. The percentage of trucks traveling faster than 70 mph was twice as large in states with uniform 65 mph limits as it was in states with different passenger vehicle (65 mph) and large truck (55 mph) speed limits.

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See Also: Automobile Accidents and Prevention; Automobile Safety Systems; Federal Transportation Policy; High Speed Highways; Traffic Laws and Enforcement.

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Sport Utility Vehicles

The concept of the sport utility vehicle (SUV) has its roots in the 1930s when Chevrolet designed a vehicle built on a truck frame with an enclosed rear cargo area and marketed it for rough roads and off-road travel. The SUV then evolved over several decades. It was not until the 1980s that the SUV began to gain popularity beyond a niche market, thanks to a combination of new environmental regulations and low gasoline prices.

Sales increased over the next two decades, despite safety concerns and a high-profile lawsuit against Ford/Firestone in 1998. By 2001, SUVs and light trucks accounted for approximately 50 percent of the new car market in the United States. However, higher Corporate Average Fuel Economy (CAFE) standards and soaring gasoline prices allowed crossover utility vehicles (CUVs) to outsell SUVs by 2006, and younger drivers continued to prefer the CUVs.

Although the term *sport utility vehicle* entered the lexicon in the 1960s, automotive historians generally agree that the Willys-Overland, first used as

a military vehicle, was an early predecessor of the SUV. In fact an advertisement in the late 1940s referred to an early civilian Jeep as a "utility vehicle" for the family. The CJ-5, introduced in 1954, is more directly linked to other SUVs, but it was in the 1960s with the introduction of the Ford Bronco, the International Harvester Scout, and the first-generation Chevrolet Blazer that SUVs intruded into the general American consciousness. Even then, they were viewed as specialized vehicles largely limited to forestry agencies, police departments, and sports enthusiasts and other consumers who wanted off-road transport.

In 1965, pickups and SUVs combined claimed only about 20 percent of American passenger vehicle sales. The 1970s saw soaring gas prices and concerns about U.S. dependence on foreign oil, and Congress passed the country's first Corporate Average Fuel Economy (CAFE) standards. The 1975 law called for a doubling of passenger-vehicle efficiency—to 27.5 miles per gallon (mpg)—within 10 years, but gave the National Highway Traffic Safety Administration (NHTSA) the authority to set less rigorous requirements for light trucks.

At the beginning of the 1980s, sales of light trucks (including SUVs) were only around 2 million, but in 1983 and 1984, lighter models of the four-wheel drive SUVs debuted. With the oil crisis past, vehicles such as the Jeep Cherokee, the Chevrolet S-10 Blazer, and, most famously, the Ford Bronco II, which sold to 700,000 customers during the decade, attracted the attention of American consumers. SUV sales increased from 132,000 in 1982 to 800,000 by 1985. By 1987, sales had increased the light truck share of the market to about one-third. The typical SUV owner was a male baby boomer, educated and financially comfortable, and while he may have been attracted to the masculine, outdoors image of the SUV, he used it quite differently than earlier sports enthusiasts. Only 10 percent or so of SUVs of the period were driven off road.

Safety

Not all news about the increasingly popular vehicles was positive. CBS's news magazine, *60 Minutes*, aired footage of the Jeep CJ rolling over while executing a turn during an Insurance Institute of Highway Safety test. By 1983, trial lawyers had learned that Bronco II prototypes were tipping onto two wheels at speeds as low as 20 miles per hour,



This photograph from the U.S. National Highway Traffic Safety Administration shows the 2012 model Ford Explorer, which is now built on a car-based unibody platform instead of its former truck-based platform. Such crossover utility vehicles (CUVs) have claimed over half of the U.S. SUV market in recent years, totaling 23.8 percent of sales by 2012, while SUVs have fallen to only 7.8 percent. Rising gas prices as well as safety concerns about the truck-based SUV models may have contributed to this shift.

a performance that caused Ford to consider and then reject abandoning the Bronco II project during development. In 1986, Congressman Tim Wirth (D-Colorado), concerned about a report that linked the stability of SUVs to the height-to-width ratio of the vehicles, petitioned the NHTSA to mandate changes in the basic design of SUVs. A broad consensus among NHTSA analysts recommended regulation, but NHTSA head Diane Steed, a Ronald Reagan political appointee, denied the Wirth petition. In 2003, NHTSA reported that rollover accidents represented 60 percent of SUV fatalities and 46 percent of serious injuries involving SUVs.

The rollover controversy failed to discourage consumers. The sales of SUVs continued to increase. In 1992, light trucks made up 37.4 percent of all passenger vehicles. The following year Chevrolet and Ford sold more light trucks than cars. Women were buying SUVs in growing numbers during this

decade. They liked riding above other traffic, and they felt they and their families were safer in the larger vehicles. Some analysts have speculated that female SUV owners were also rebelling against the “uncool” image of the soccer mom in her minivan, which had become fodder for the nation’s comics.

In the late 1990s, Ford added the Expedition and Excursion to its lineup, and General Motors added the 4-door Chevy Tahoe and 4-door GMC Yukon. These larger SUVs had larger engines and price tags that were comparable to the mid-size SUVs such as the Explorer, the Cherokee, and the Blazer. Perhaps the large SUVs served as a countersignal to the culture’s demand for downsizing. At any rate, in 1990, 74,000 large SUVs were sold in the United States. By 2009, that number was almost 2.5 million.

Scandal touched the SUV again in February 2000 when a Houston television station broke the news of tread separation problems of Firestone radial

Wilderness ATX tires on Ford Explorers. Later that year, after reports of 33 crashes resulting in 27 injuries and 4 deaths, NHTSA began a formal investigation. Bridgestone/Firestone recalled 6.5 million tires in August 2000, and less than a year later, Ford recalled all 13 million Firestone Wilderness ATX tires that remained on its vehicles.

In November 2000 President Bill Clinton signed the Transportation Reporting Enhancement, Accountability and Documentation Act (known as the TREAD Act), which included early a warning system to detect safety-related defects in automobiles. In October 2001, NHTSA agreed that some Firestone tires tended to separate and required the company to recall an additional 3.5 million cars.

The scandal cost Bridgestone \$1.6 billion in the year after the scandal. Ford's recall cost the company \$3 billion and a brief reduction in market share, but in 2002 the Ford Explorer, widened by two inches and with independent rear suspension, was again America's best-selling SUV, selling ahead of its closest competitor by more than 180,000 vehicles.

Conclusion

By 2005 gas prices exceeded \$3 per gallon, a landmark in American automotive history. Soaring gas prices and economic recession did what safety concerns could not do. The crossover utility vehicle (CUV) was born in 1996 when Toyota introduced its RAV4, which looked like a small SUV but was built on a car chassis rather than a truck chassis. Three years later the Lexus RX, followed by the BMW X5 the next year, revealed the luxury potential of the CUV.

By 2006, when Ford Motors announced that the next Ford Explorer would transition from a truck-based platform to a car-based unibody platform, CUV sales accounted for more than half of the U.S. SUV market. In 2002, crossovers represented 7.7 percent of sales; in 2012, the number rose to 23.8 percent. SUVs, by contrast, claimed about 18 percent of sales in 2002, but fell to about 7.8 percent of sales in 2012.

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See Also: Automobile Accidents and Prevention; Automobile Culture; Automobile Design; Automobile Manufacturing and Sales; Automobile Travel Patterns.

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State Highway Planning and Finance

Considering the vast geographical area of the United States and the strength of its economy, the extent of its highways should not be surprising. According to the U.S. Census, in 2008 there were 4,059,000 miles of roads in the United States. Though the interstates of the National Highway System seem to be everywhere, they in fact make up only about 1 percent of the country's total road network. Local (city, town, county) roads comprise the majority of all roads, but a smaller, though extremely important part of the highway network in the United States, is managed at the state level.

On the most basic level, a state highway is any highway that has been legally designated as such by one of the states. State legislation can make further distinctions, separating state highways from city, town, or county highways. Aside from the fact that simply designating a road as a state highway makes it one, there are definitive aspects that separate them from the federal highways. One factor, however, that is consistently recognized is that state highways exist within the confines of the state borders; they do not cross those borders.

For example, Massachusetts Route 2 crosses the border with New York and becomes New York Route 2, but all Massachusetts control and liability ends at the state line, where it is assumed

by the New York Department of Transportation. State highways do, however, cross municipality or county borders.

Further, state highways are directly funded by revenues allocated by the states, although some funding is received from the federal government. How each state funds its highways is a critical matter, because how money is to be raised in economically difficult times is one of the major responsibilities of the state agencies charged with not only maintaining this infrastructure but also expanding it to fit the needs of the state's economy.

State highways are also not subjected to the same design and construction standards imposed on roads that are part of the interstate highway system. While some state roads were grandfathered into the original National Highway System when it began in the mid-1950s, the federal government's standards for its highways are quite stringent and non-negotiable. These requirements include criteria concerning the number of lanes, width of lanes, width of "breakdown" lanes, banking, grades, the speed that can be sustained, and other factors.

Historically, the funding and management of auto highways has been a state responsibility. States were more active in this field until the National Highway System came into being and states are still very active. Generally, highway funding, planning, policy, safety, and other operations are carried out by each state in a similar fashion.

Every state has some statewide agency that is responsible for its highways. Usually designated as the Department of Transportation (DOT; or transportation cabinet, agency of transportation, or department of roads), this organization may also exercise oversight for other transportation modes, such as air or maritime. In every case there is a highways section that is responsible for all (or nearly all) aspects of managing highways and the resources needed to keep them operating.

At the state level, policies concerning highways are developed and promulgated by the highway department of the state DOT. The standard understanding of what constitutes a policy (regulatory measures, system of laws, funding priorities) applies here but in terms specific to highway operations, funding, and safety. Highway environmental issues such as water runoff and noise are covered as well. Since the advent of the Internet, state DOTs and their subordinate highway departments make these

policies widely available to the general public as well as roadway contractors or transportation advocates to review.

Planning Process

The continued safe and effective operation of state highways relies upon a planning process that takes into account not only finance but also the economic and social needs of the state. In addition, the political realities of the state have an influence. The governor of the state sets his or her priorities, which the Highway Department translates into its plans. The political climate in the state legislature also has an influence. These two sources of influence as well as what experts in the highway agency consider to be the objective needs or desired goals must be combined.

The plans that are eventually published serve several purposes. First they present a long-range statement of what is considered to be the vision for maintaining and improving the highway system. Typically, these plans cover several years, ranging from three years in some states to 20 or 30 years in other states. The published state highway plan not only articulates the vision but also puts it into a form that helps its advocates to sell it to legislators and the public. Behind the formal plan as it is presented is a great deal of work. The plan, in its real form—not only the glossy presentation—must take into account many factors in order to successfully address the technical and logistical details involved.

Highway planning is a classic case of long-range planning that incorporates a large number of stakeholders. Typically, expanding the capacity of already existing highways requires six to eight years, and 10 years of planning is not uncommon for new highway development. Ultimately, the planning process alone will need to consider technical factors of design and construction as well as in-depth studies of the economic and social factors that will affect and be affected by the highway project. Environmental impact assessments must be completed, which explore different alternatives to the basic plan in order to allow planners to select the most environmentally friendly course of action. Environmental studies, once approved, inform the remainder of the development process and are followed by the purchase or other form of acquiring the land needed, if that is the case.

Highway design in both preliminary and then advanced and detailed stages follows. The design of highways is such a technically involved process that in all likelihood no one state can muster the expertise to perform it successfully on its own. There is one resource that exists that enables states to improve existing highways and to develop new highways using the latest advances in design. Every state DOT has joined an organization, the American Association of State Highway and Transportation Officials (AASHTO), which provides expertise derived from experience, design committees, and research. AASHTO is also responsible for the publication and maintenance of standards for the design of highways.

Funding for Construction and Maintenance

After the planning process has been completed, construction can begin. But at the same time that technically realistic and politically feasible planning for highways on the state level takes place, the financial aspects must also be studied and resolved. Financing highway development and maintenance has become perhaps the most complex issue facing all state highway departments and DOTs.

The economic situation in the United States in the past decade has presented challenges to financing highway work. Even with the economic downturn and other factors that make collecting revenue more difficult, highways and roads still deteriorate. Despite a slowing economy, consideration must still be given to expanding highways in order to provide the type of infrastructure that cities need today and for the future.

Fuel taxes have always been a means of collecting revenue for federal and state highway funding (local roads are usually financed by property, sales, and other taxes). In the first decade of the 21st century, fuel taxes accounted for approximately one-third of state highway revenue.

Although gas taxes have existed since 1932, in the past 20 years, they have not been as dependable or as significant a source of revenue as they once were. There are several reasons for this. Better gas mileage in vehicles (which decreases the number of gallons purchased) has been a major factor. Another aspect to this problem is that gas taxes have not kept pace proportionally with the increase in the price per gallon. In addition, the revenue raised through taxes on fuel has not kept pace with the increases in labor



A New York State Thruway sign below the Interstate 87 shield in Ramapo, New York. State highways like the New York State Thruway are directly funded by revenues allocated by the state, although some funding is received from the federal government.

and materials costs associated with highway repair and construction. Finally, purchases of trucks to haul freight on the highways have declined, further eroding a source of additional traffic and income.

Had fuel taxes been raised as frequently and in proportion to increases in the price of gasoline, they would be several times their current rate. This is generally true for the states just as it has been at the national level, where no raises in the federal fuel tax have been made since 1997 (as of 2013). In the past, as is the case with any tax, fuel taxes have been increased with relatively little opposition.

One reason for the lack of significant opposition was the fact that the tax revenue went directly to roadway maintenance and improvements, which benefited all users. In the current political atmosphere, however, raising taxes of any kind, even

those that not particularly unpopular, is increasingly difficult.

One alternative to fuel taxes that has been discussed is a charge based on vehicle miles traveled (VMT). One argument in favor of this kind of tax is that it puts the burden of payment on users in proportion to their actual road use. Others argue that this would be bad policy as it would penalize those who purchase fuel-efficient vehicles. There have also been privacy objections raised, as collecting the tax would require acquiring data on individual automobile use. Fortunately for state highway finances and planning, there are other sources of income. These include tolls (and their increasingly creative application), other user-related fees (such as registration and license fees), and federal aid in the form of regular grants and those received from the American Recovery and Reinvestment Act (ARRA) of 2009.

Toll Roads

Toll roads are a fact of life in the United States and have been since the 19th century, when the construction of new roads was financed by levying tolls on traffic. In the 20th century, making a road a toll road was a common practice, as it still is. In states such as Florida, New Jersey, New York, Pennsylvania, and Illinois, road tolls account for at least 10 percent of their total highway revenue.

In some instances in the past, the tolls were removed when the highway was paid for. In other instances, the tolls have remained in place for decades to continue financing highway maintenance. In some instances, tolls are being reinstated on roads. In some locales, such as Texas, newly opened roads are now routinely starting their existence as toll roads. While that approach can be expected on the basis of paying for new construction, it also can be seen as a reflection of the current political situation, where there is less willingness for a political entity to require all of its citizens to pay for something (through fuel taxes) that benefits one region. In this way, the expectation is that those who benefit directly will pay directly for construction and, presumably, for upkeep.

There have also been two variants on the use of highway tolls. Private funding for the construction of new roads in some instances has been implemented. In these cases, the private financial entity finances the roads and in return receives an agreed-upon percentage of tolls for a specified time period.

Another means of using tolls has been to charge variable tolls for the use of certain routes at specified times of day. Routes that are not as congested during rush hour traffic are now sometimes charging an increased toll rate. The idea is that if a driver wants to cut commuting time and uses a particular route to do so, he or she must pay an additional amount. This last solution has been tried but has not reached wide use.

Other Revenue Sources

In all cases described above, the revenues come to the state as a result of payments in one form or another by users. According to the Federal Highway Administration, however, there has been a decrease not only in fuel taxes as a source of income but all of these user-related fees are bringing in less income than before. At the end of the first decade of the 21st century, this user revenue amounts to only half of the funding used for highway construction and maintenance.

For that reason, assistance from special programs (such as issuing bonds by states) is required. The main source of revenue for the remaining 50 percent of needed funding is federal aid. One direct source of aid as well as a source of management, risk, and safety advice to the states is the Federal Highway Administration (FHWA). Coming into existence in 1966 as part of the U.S. Department of Transportation (USDOT), it oversees the federal funds disbursed to the states for maintenance and construction of state highways as well as activities on the National Highway System.

In addition to its long-time oversight responsibilities, the FHWA exercises the same function over part of the funds available through ARRA grants. Of the total American Recovery and Reinvestment program, \$48.1 billion is allocated to the Transportation Income Generating Economic Recovery (TIGER) Grants. Of that, over 50 percent is to be distributed to the states for highway and bridge construction. Thus, even for state highways, there is a significant amount of funding that comes from the federal government.

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See Also: American Association of State Highway and Transportation Officials; Highway Construction

and Maintenance; Highway Design and Engineering; Highway Finance; Highway Planning; Highway/Road Capacity; Vehicle Miles Taxation and Fees.

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State Implementation Plans

A state implementation plan (SIP) refers to a collection of reports that details a specific program of forward-looking environmental initiatives, policies, and rules established by states, territories, and the District of Columbia. Local and state agencies are obliged to file the SIPs with the U.S. Environmental Protection Agency (EPA) to indicate their intention to implement specific measures to attain and maintain the National Ambient Air Quality Standards (NAAQS) for primary- and secondary-criteria pollutants. The measures pay particular attention to bringing predesignated polluted zones (nonattainment areas) under their jurisdiction into compliance with federal standards for clean air.

The SIP is a way to compel both local and state authorities to move decisively and pragmatically to respond to pollution alarms before the air quality has been too thoroughly compromised. SIPs, then, provide the mechanism for speedy and directed response to air pollution concerns. The SIP itself is an often massive document filed with the EPA and available for public inspection (indeed, most states maintain a Web site specifically to detail such compliance initiatives as a way to promote an environmentally friendly spirit and help attract

both new residents and new businesses). The SIP is a broad, comprehensive document with four necessary parts: the narrative, which stakes out the dimensions of the problem and provides critical statistical data on air quality matched against federal standards; the rules, which outline the specific programs for addressing that pollution; the technical documentation, which provides the scientific backup for the proposed programs and verifies that the programs are not only doable but also practical, with specific and immediate benefits; and the legal agreements, which provide mandatory documentation signed by local and state officials as well as the state EPA representative.

It would be a misperception, however, to assume that despite such mandatory elements and tidy divisions the typical SIP is an actual report stored in some computer file or handed around in a three-ring binder in the EPA offices in Washington. In fact, seldom do the filed documents actually include specific plans for addressing the affected areas—rather, the SIP documentation demonstrates that the state understands the problem and its dimension and that it has every intention to pursue means to effect the maintenance, restoration, enhancement, or protection of its nonattainment zones.

A typical SIP can run to hundreds of pages in the state's efforts to provide a sufficient record of public and industry responses, measurements of pollutants, listings of federal regulations, environmental emission models, and data sets on non-compliant areas. Each initial SIP covers a five-year period in which the state identifies how it plans to achieve any pollution reductions to meet the federal clean air standards. Updates are required every three years thereafter to ensure continued compliance.

It is up to local and state authorities to develop specific programs or to implement new policy guidelines to achieve the designated numerical standards, with the EPA monitoring their progress. In this way, the SIP represents a bold initiative in federal and state cooperation, a partnership among local, state, and federal departments as well as the general public.

As a first step in filing an SIP, state and local environmental agencies enter monitored air quality data into a mathematical model that in turn matches the data against the federally mandated numbers and comes up with a kind of baseline figure that measures the range of compliance. As with any

calculations that involve the environment, however, the numbers are never simple.

Indeed the model used by the EPA in connection with the SIP program is quite complex. The determination of nonattainment status, after all, needs to factor in a wide range of variables: average wind speeds, tree and brush growth, traffic patterns, atmospheric chemistry, water resources, highway system integrity, demographics and population distribution, and recurrent weather patterns. Once the data indicates a problem, the process enters its second stage as local agencies begin to consider possible solutions.

At a time of increasing conflict between the federal and state governments, SIPs have evolved in an environment of cooperation and shared responsibility. But the expectation is clear: quantifiable results that are sustainable, enforceable, and permanent. The overall purpose served by an SIP, then, is actually twofold: (1) to reassure federal environmental watchdogs that the state has, in fact, a strategic initiative in place to monitor and control air pollution; and (2) to indicate the specific federal emissions control requirements that will guide whatever initiatives the state will undertake.

Each SIP must be signed by local and state authorities and approved by the EPA. The EPA, in turn, monitors the progress in cleaning up any nonattainment zones—failure to comply within a reasonable time frame provides the EPA the authority to levy fines to compel compliance, withhold federal project dollars, and, in extreme cases, pursue criminal action.

The authority for the federal government to act as watchdog of the nation's air quality dates to concerns first raised immediately after World War II about air quality in the Northeast Corridor. But specific actions to monitor air quality were begun with the federal Clean Air Act of 1963 (CAA), a part of the John F. Kennedy administration's bold (and groundbreaking) environmental policy initiative.

By contemporary standards, of course, the initial version of the CAA seems soft and inexact—providing little more than incentives for local and state governments to become aware of the increasing volume of air pollution in cities and its effect on public health while funding programs designed to devise possible strategies for cleaning up the air. The thin authority structure and vague criteria used in that initial law gave the program little chance for significant success.

When the federal act was revisited for its renewal in 1970, legislators, acting on the counsel of blue-ribbon committees of environmental scientists now alarmed over the unchecked spread of unhealthy air, passed a far stricter bill that actually provided ranges for acceptable and unacceptable levels of air pollutant emissions. Within the year, the EPA was established and put in charge of monitoring compliance nationwide, recognizing that any success in containing and controlling air pollution had to be decentralized, as state-to-state air quality was shared but appropriate attention to controlling it was not.

In addition, the EPA recognized that, unlike the wider and more open spaces of the west (save California), the Midwest states and, particularly, the Northeast basically shared the same "airshed"; thus, providing standards for clean air was a federal rather than a state concern. Under the provisions of this version, the EPA was given specific authority to actually limit emissions from such traditionally heavy polluters like factories, mills, and utilities. This provided the federal government with unprecedented responsibilities for environmental advocacy.

Over the next decade, as the EPA became embroiled in a number of very public scandals involving the illegal distribution of cleanup monies, new concerns were voiced over the sprawling (and often unchecked) authority the administration had been given. When the bill was renewed again in 1990, recognizing the size of the investment necessary to address the nation's air quality, provisions encouraged cost-effective protocols for reducing air pollution, requesting states target small-range projects to attain goals over a period of time rather than sweeping changes that could negatively affect state budgets. And during the Bill Clinton administration, with its emphasis on business-friendly environmental policy that encouraged practical and specific goals, the EPA moved to make air quality control manageable with results that were both real and measureable.

The SIP, as an instrument of compliance intentions, provided exactly that. Using its broad authority, the EPA designated six specific, common pollutants to measure for compliance, pollutants known to cause damage to property and the environment and also to cause long-term health problems. The six are ground-level ozone (smog), particulate matter

(a kind of pollution soup, often described as haze, comprised of liquid droplets and a variety of coarse inhalable particles—more than 10 micrometers in diameter or smaller and including particle acids, carbon-based chemicals, metals, common dirt, and even dust), lead, carbon monoxide, nitrogen dioxide; and sulfur dioxide. These are designated as criteria pollutants because the EPA sought to control them by providing specific (and stringent) criteria for acceptable and unacceptable levels. By designating specific pollutants, the EPA provided the frame for state by state compliance.

The SIP forecasts levels of pollutant emissions that will achieve the NAAQS (the “emissions budget”) and identifies pollution control strategies that will enable steady progress toward attainment of these air quality standards by the applicable deadlines set by the CAA. The SIP reassures the federal government that all states have both the capacity and the specific initiatives to meet those standards.

When an area, most often a metropolitan area or an area of significant industrial development, fails to attain the compliance level for one or more criteria pollutants, local authorities, along with business and industry representatives, stake out specific short-term projects that will reduce the level of those pollutants in the designated area.

In addition, the SIP must provide long-term strategies for continuing to ensure air quality is maintained at acceptable levels. Importantly, under the federal CAA, transportation activities that receive federal funding or approval must be fully consistent with the SIP. These include the 20-year regional transportation plan (RTP), or a short-term transportation improvement program (TIP), which if implemented must not result in emissions that exceed the SIP’s emissions budget. Additional transportation control measures (TCMs) may be required if needed to reduce vehicle emissions due to traffic congestion or growth in the overall number of vehicle trips and/or travel miles.

Of course, the EPA, with its broad authority, can reject an SIP and create its own strategy for compliance (a document known as a Federal Implementation Plan, or FIP); but such actions are rare. The reality of managing state resources and reallocating public monies to address air quality requires extensive familiarity with local political structures, regional industrial bases, particular geographic features, housing patterns, population dispersal, and

economic factors; thus, the EPA generally leaves specific compliance strategies to the local levels.

SIPs are a matter of public record and are readily available for review on state Web sites. Of course, public advocacy groups pushing for more stringent standards in the face of growing concerns over climate change may find much in SIPs to disparage. However, the SIPs have been largely lauded for pressuring local governments to maintain air quality for the common good. Although the SIPs themselves are not required to itemize specific programs designed to bring air quality into alignment with federal standards, the range of programs initiated as a result of SIPs is not only impressive but represents the innovative, resourceful, and technological creativity of state and local governments when they are directed to resolve a particular pressing problem.

Measures taken to improve ambient air quality in reaction to SIP reviews can include broad, regional programs with massive price tags or relatively modest programs that nevertheless achieve significant results. SIPs have been responsible for improvements to public transit systems; traffic flow redesign to minimize starting, stopping, and idling, all heavy contributors to emission levels; bans on open burning; the construction of serviceable bicycle paths and pedestrian walkways; programs designed to encourage flexible work schedules to decrease rush hour traffic; the construction of high occupancy vehicle (HOV) lanes to encourage carpooling; upgrading industrial and plant equipment to reduce emissions; redesigning traffic flows by constructing multilane off-ramps; and funding private enterprise and university research teams to improve emissions equipment on all vehicles, particularly those more than 10 years old.

There have been problems. Despite the much touted federal–state partnership, limits to federal funding and support make the SIP a resource-intensive operation for local and state governments. The process itself is heavily bureaucratic involving accumulated (and redundant) paperwork. The process of filing the SIP is complicated and time-consuming. But perhaps the most directed criticism of the SIP process is that it compels states to focus on generating figures demonstrating attainment in the plan rather than tracking the methods for achieving those numbers. But on the whole the SIP program has worked—levels of criteria pollutants have

consistently been dropping since 2000, and air quality in major cities is quantifiably cleaner.

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See Also: Carbon Dioxide Emissions; Carbon Monoxide Emissions; Clean Air Act and Amendments; Environmental Impacts; Environmental Protection Agency; Federal Transportation Policy; Mobile Emissions; National Ambient Air Quality Standards; Nitrogen Oxides; Particulate Matter; Regional Transportation Plans; Transit Planning, International; Transportation Improvement Programs; Vehicle Emissions Standards.

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State Transportation Planning

Each state as well as Puerto Rico and the District of Columbia has an agency or department officially charged with the responsibility of transportation planning, generally designated as the Department of Transportation (DOT). Typically, these departments not only have responsibilities for the planning, operation, and maintenance of multiple modes of transportation (air, water, and surface) but they also must work cooperatively with other agencies involved with transportation.

Since Congress passed the Federal-Aid Highway Act of 1962 and tied federal funding of surface transportation to meeting certain requirements, states, through their departments of transportation, have also been charged with ensuring that statewide transportation planning conforms to federal regulations.

The organization of the departments of transportation and the policies through which the state allocates responsibility, manages personnel, and establishes procedures and practices to perform tasks associated with the planning process vary from state to state, but all state DOTs are involved in activities such as managing transportation planning, coordinating projects among various agencies, involving the public in procedures for transportation planning, and working on intermodal planning and congestion management.

The transportation planning process of each state must address both urban areas and areas outside metropolitan areas. Since the 1970s, states have had to coordinate planning for urbanized areas with metropolitan planning organizations (MPOs), organizations in urbanized areas with a population of 50,000 or more that are mandated and funded by the federal government. Any urban transportation project that receives federal funds must come from the appropriate MPO and the state transportation planning process. For projects in areas not covered by an MPO, states must provide opportunities for local officials to participate in the planning process. Some states meet this requirement through rural planning organizations, typically voluntary organizations through which local officials arrive at consensus on regional transportation priorities.

In 2012, federal law authorized the creation of the Rural Transportation Planning Organization (RTPO). The change gives such groups greater status, although the choice to create an RTPO still rests with each state. Some already existing rural planning organizations serve multiple rural counties with combined populations exceeding the minimum 50,000 of an MPO.

Long-Range State Transportation Plan

In order to receive federal funding, states are required to develop a long-range statewide transportation plan that identifies a state's direction for its transportation investments for a period of at least 20 years. Within this general requirement, the plan

may vary widely in content and approach. Some states develop a needs-based plan. They consider the existing transportation system and identify current and future needs based on demographic and transportation trends and projections. Others prefer vision-based plans that focus on an ideal image of what the state's future transportation system should be. Still others are policy based, describing strategies that will be used to achieve goals and official public policies for solving problems and meeting demands.

Project-based plans offer another option. States choosing this approach identify specific projects to meet identified needs and may even include projected costs. Other states have corridor plans that consider specific transportation corridors and their needs. The best of these plans include all transportation modes and refer to both passenger and freight needs. A final category is the fiscally realistic plan that sets the state's long-term direction with due consideration of projected capital, operating costs, and revenue sources. Some states may combine two or more of these approaches.

Regardless of differences, each plan must include information on the development and implementation of a multimodal transportation system for all areas of the state and provide for public comment before the plan is published. Legislative changes in 2012 added the requirements that the long-range plans of the states must include a description of the performance measures and targets used in assessing system performance as well as a system performance report and subsequent updates evaluating the condition and performance of the transportation system in relation to the performance targets.

Unlike MPO plans, which must be updated every four or five years and are required to identify project costs and revenue sources, the long-range transportation plans of the states are required to be updated only as needed and are not required to include specific projects or to explain fiscal constraints if projects are included. However, state DOTs must have a documented process for consulting with officials in nonurban areas and with officials of Native American tribes. Although states are required to provide copies of their long-range transportation plans to the Federal Highway Administration and the Federal Transit Administration, the plan does not require the approval of any federal agency.

State Transportation Improvement Program

Each state must also develop a state transportation improvement program (STIP). This document covers at least a four-year period of the state's program of transportation projects that are to be financed by federal surface transportation funds. The STIP also includes regionally significant projects that require action by the Federal Highway Administration or the Federal Transit Administration, whether or not the projects are federally funded. Each project included must be consistent with the state's long-range transportation plan as well as with any relevant long-range metropolitan transportation plans. Fiscal constraints are also in effect for all projects. The state is allowed to include only projects or project phases for which full funding can be reasonably anticipated within the specified time frame of the project.

Each MPO in the state is required to have a transportation improvement program for federally funded projects for the next four years. Federal law requires that each MPO transportation improvement plan, or TIP, be included without change in the state transportation improvement program, directly or by reference. Additionally, MPOs serving urban areas with a population in excess of 200,000 are required to have a congestion management process that specifies congestion-reducing actions and strategies. Most states include state-funded projects in their plans as well, but all federally funded projects must be included in the STIP before the Federal Highway Administration or Federal Transit Administration can authorize the expenditure of federal funds.

When the state submits the STIP to the Federal Highway Administration and the Federal Transit Administration for review and approval, each agency reviews the plan, and they jointly declare the extent to which the STIP is based on a process that meets or substantially meets the federal planning requirements that include but are not limited to the demonstration of fiscal constraints, the use of a documented process for involving the public and consulting with officials outside MPO areas, and including MPO transportation improvement programs in the STIP.

New Projects and Federal Funds

Congress established the Office of Road Inquiry in 1896 and passed the first Federal-Aid Road Act in 1916. That act created the Federal-Aid Highway Program through which funds were made available to state highway agencies to help improve

roads. By the 1920s, the Office of Road Inquiry had become the Bureau of Public Roads, and the Federal Highway Act of 1921 authorized the newly named agency to channel funds to the states to help in the construction of a paved system of two-lane interstate highways. When the Great Depression of the 1930s struck, the Bureau of Public Roads assisted state governments in creating road projects that gave jobs to thousands of the unemployed.

World War II turned the focus to roads needed for defense, and President Franklin Roosevelt signed legislation in 1944 authorizing a network of rural and urban express highways called the National System of Interstate Highways. The Bureau of Public Roads, which had been renamed the Public Roads Administration (PRA), implemented Section 7 of the law, asking the states to submit recommendations for routes to be included in 40,000 miles of the new interstate system. The PRA also worked with state and local officials to make interstate plans for larger cities.

The 1950s saw the beginning of what was called the “greatest public works project in history.” The Federal-Aid Highway Act of 1956 expanded the interstate system to 41,000 miles and authorized \$25 billion for fiscal years 1957 through 1969. Highway construction employed tens of thousands of workers and eventually helped the interstate trucking industry surpass railroads to gain the dominant share of the domestic shipping market. Fast food chains, hotels, and amusement parks proliferated, and a decade later America had become a nation of drivers. The Highway Revenue Act, also passed in 1956, created the Highway Trust Fund and provided that revenues from certain highway-user taxes would be credited to the fund to finance the expanded highway program enacted in the Federal-Aid Highway Act of 1956. Ninety percent of the highway costs were covered by federal appropriations, and 10 percent by the states, which were also responsible for awarding the construction contracts and managing day-to-day maintenance operations and law enforcement.

The 1960s brought the Federal-Aid Highway Act of 1962, an act that authorized federal highway funding for fiscal years 1992 through 1997 and for the first time linked federal funding to conformity to specific requirements, forever changing the roles of the federal government and the states in the area of transportation funding. The new law also made

the four-cent gas tax permanent and adjusted other excise taxes. It adjusted remaining authorizations for the system to a total of \$25.2 billion over nine years. With the states’ matching funds, the legislation accounted for \$27 billion in funding for the remainder of the program through fiscal year 1971, the same amount Congress had thought in 1956 would be the total cost of the program. Four years later, the Department of Transportation was officially established, with the Bureau of Public Roads undergoing a name change to the Federal Highway Administration as one of its divisions. Throughout the 1970s and 1980s, the Federal Highway Administration worked with the states to open 99 percent of the designated 42,800-mile interstate system—officially called the Dwight D. Eisenhower National System of Interstate and Defense Highways.

ISTEA and the Next Revolution

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) moved transportation regulations and funding into the post-interstate era. The \$155 billion act revolutionized transportation planning and the relationship between the federal government and the states. ISTEA stressed intermodalism—the connections among highway, rail, air, and marine transportation. The statute also gave state governments greater flexibility in finding solutions to their problems. Federal funds could be used for projects that alleviated traffic congestion, increased safety, and improved air quality. With four decades of interstate highway system construction in the past, ISTEA emphasized maintenance rather than expansion. It established an Interstate Maintenance Program for resurfacing, restoring, and rehabilitating the interstate highway system.

One of the most significant changes was the Surface Transportation Program (STP), which did not limit federal highway funds to highways and transit projects but allowed states to use federal dollars for a range of projects that supported the intermodal concept, including bridges on public roads, transit capital projects, carpooling projects, safety improvements, bicycle and pedestrian facilities, and transportation control measures. Another intermodal initiative, the Congestion Mitigation and Air Quality Improvement Program, enabled states to direct federal dollars toward innovative projects that did such things as establish rideshare services, promote employer trip-reduction programs, and

support bicycle and pedestrian travel—all with the goal of improving air quality and reducing traffic congestion. At first, use of these funds was limited to projects in areas that failed to meet national air quality standards set by the Clean Air Act, but later changes in the law allowed the funds to be used to maintain air quality in areas that were in compliance with federal standards.

One of the most popular features of ISTEA with the public was the Transportation Enhancement Program, which supported construction of pedestrian and bicycle facilities, acquisition of scenic and historic sites, rehabilitation of historic transportation facilities, archaeological planning and research, control and removal of outdoor advertising, and mitigation of water quality effects from roadway runoffs.

In 1998, the Transportation Equity Act of the 21st Century (TEA-21) became the successor to ISTEA. TEA-21 authorized more than \$200 billion to improve transportation infrastructure, enhance economic growth, and protect the environment. New regulations emphasized environmental concerns particularly. Ten percent of Surface Transportation Program (STP) funds (\$3.3 billion over six years) was set aside for transportation enhancements, including a wide range of environmental and water quality improvement projects such as pollution abatement and mitigation projects.

TEA-21 also allowed as much as 20 percent of the cost of a transportation facility reconstruction, rehabilitation, resurfacing, or restoration project under the STP to be used for environmental mitigation, pollution abatement, or construction of storm water treatment systems. Also, states were allowed to use STP and National Highway System funds for wetlands projects designed to offset impacts from past transportation projects. The federal share for some TEA-21 and restoration projects, depending upon program requirements, was 80 percent.

TEA-21 also offered a new planning tool: guaranteed funding. For the first time, protections prevented spending for highways, highway safety, and transit from being reduced to increase spending for other discretionary budget programs. Guaranteed amounts for highway spending were linked to actual Highway Trust Fund receipts, and only projects eligible under federal highway and highway safety programs could be supported by these funds. Guaranteed funding gave states the ability to plan

transportation programs with a reasonable expectation of having the funds to finance them.

In 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), as the acronym suggests, targeted safety concerns, nearly doubling funds for infrastructure safety and including programs that focused specifically on concerns such as work zones, older drivers, and pedestrians, including children walking to school. Building on TEA-21's guaranteed funding, SAFETEA-LU included an Equity Bonus program that ensured that each state's return on its share of contributions to the Highway Trust Fund (in the form of gas and other highway taxes) was at least 90.5 percent in 2005 and reached a minimum 92 percent relative rate of return by 2008. Every state was also ensured a specified rate of growth over its average annual TEA-21 funding level, regardless of its trust fund contributions.

Among SAFETEA-LU's most substantial provisions was the retention of TEA-21's environmental programs with increased funding. The law added new environmental programs, including a \$100 million pilot program for nonmotorized transportation. The funds were divided equally among four communities: Columbia, Missouri; Marin County, California; Minneapolis–St. Paul, Minnesota; and Sheboygan County, Wisconsin. The goal of this 100 percent reimbursement project was to construct a network of nonmotorized transportation infrastructure facilities (including sidewalks, bicycle lanes, and shared-use paths that connect directly to transit stations, schools, residences, businesses, recreation areas, and other activity centers) to demonstrate a mode shift from motorized travel to bicycling and walking transportation.

Delayed Action and Questions for the Future

After a series of extensions and a delay of more than three months after the expiration of the previous law, Congress passed the Moving Ahead for Progress in the 21st Century Act (MAP-21) in summer 2012. The legislation consolidated or eliminated more than 70 federal programs. It also required states, localities, and transit agencies to establish performance targets and incorporate them into their transportation plans and project selection, and made major reforms and improvements to the project delivery process.

This reform brings welcome relief to states that often must wait several years, sometimes as long as 14 years, to complete projects that require federal funding. Other changes include the Cardin-Cochran provision that provides grants to local communities to make their streets safer for walking or biking, although at a lower amount than supporters hoped. About half the money is designated for metropolitan areas, with the remainder used at state discretion. MAP-21 also created a new program that provides relief for public transportation systems that are affected by a natural disaster or catastrophic failure. This program has already been utilized by the states and transit agencies impacted by Hurricane Sandy.

MAP-21 is set to expire on September 30, 2014. Politicians and pundits predict that the Highway Trust Fund from which the federal share of transportation programs is funded almost entirely will be insolvent starting in fiscal year 2015. By the end of 2014, a total of \$54 billion will have been transferred from the General Fund into the Highway Trust Fund to maintain its solvency. This includes an \$18.8 billion transfer authorized by Congress in MAP-21.

On average, states depend on federal funds for half their annual capital spending on bridges and highways. Some states rely even more heavily than the average. Federal dollars fund more than 70 percent of transportation spending in 10 states, and in the two states with the lowest gasoline taxes in the nation, the amount is considerably higher: 79 percent in South Carolina and 93 percent in Alaska. States have responded to their precarious position in a variety of ways. Some have raised state gas taxes, some have replaced gas taxes with sales taxes, and some have sought private-sector financing. Others are experimenting with toll roads or fees based on miles driven. Meanwhile, lawmakers continue their partisan battle on the issue of higher gas taxes, and state transportation planning faces an uncertain future.

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See Also: Bureau of Public Roads; Federal Aid Highway Program; Federal Highway Administration; Federal Transit Administration; Highway Finance; Highway Trust Fund; Interstate Highway System; Metropolitan

Planning Organizations; Surface Transportation Program; Transportation Planning.

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Street Design/Patterns

Street designs evolved rapidly during the late 19th and all of the 20th century because of the invention of the combustion engine and the development of the private motor car. As more people became car owners, cities expanded to meet the desire of people to live further away from city centers in suburban areas where open space was plentiful and travel was easy. As the 20th century continued, different forms of street patterns were designed and built to accommodate the rapid growth of cities. However, this led to conflict between motor users and pedestrians as roads became barriers to walkability.

Street designs in most cities around the world are often the result of three different types of interactions: the main form of transport in use at the time of the city's formation, the various planning policies over the years, and the growth that the cities may have experienced during their existence.

Street designs, however, are also conducive to the quality and social interaction that takes place within any community, linking different parts of neighborhoods and providing access to all parts.

Origins of the Grid Layout

For long periods of time in Europe, most cities followed the “gridiron,” or grid, layout of roads made popular by the Roman Empire 2,000 years ago. This involved a series of roads running parallel with another series of parallel roads intersecting with them at 90 degrees. This layout, originally intended for the ease of walking and simple in its design and simplicity, was repeated throughout the Americas when European settlers arrived in the 17th century.

In America, the grid layout was adapted to take account of the vast open spaces and tracts of land that the pioneers encountered. The Northwest Ordinances carried out in 1785 and 1787 established the pattern for the grid for American cities. This created six-mile squares across the continent, leaving these squares simple to survey, easy to divide, and establishing everything at right angles.

Apart from a few exceptions, this method of street design was accepted as the easiest method of planning and design. This allowed for its “blocks” to be easily surveyed and recorded for ease of ownership, as well as ease of pedestrian movement around the city. It was not until the advent of the combustion engine and the motor car that the grid system of street layouts slowly began to change.

The advent of public transport—before the motor car came into existence—allowed workers (commuters) to live farther away from their workplace and provided efficient longer-distance commuting. This led to suburbs springing up on the edges of cities that once again used grid patterns but sometimes incorporated diagonal streets, making pedestrian access to public transport accessible. As the passenger numbers increased, the main stops and terminals became social and commercial centers, shaping the future layout and planning of these areas.

Advent of the Automobile

It was the introduction of the motor car, and the ability of the middle and working classes to purchase one, that led city planners to be released from the constraints of having to plan mainly for the pedestrian. The grid pattern was the mainstay of most city road layouts until the growth of people owning their own vehicles caused a series of gridlocks in many populated cities.

As suburbs rapidly grew and expanded in cities around the world in the 1920s and 1930s and as the number of motor vehicles grew from 2 million in 1915 to almost 10 million by 1920 in the United States, planners were being driven by the demands of the motor car rather than pedestrian movement and public transport. Indeed, it is only nearly a century later that the problems caused by the motor car in the development of the cities are finally being addressed.

The motor car revolutionized the way suburban street design developed. With everything in and around the city within easy reach, the traditional planning of a city made on the premise that most things had to be within walking distance was swept away and planning based on the car took precedence, mainly involving an increase in the traveling speed. However, with the car literally driving the direction of these new suburban areas, it brought with it its own disadvantages. Suddenly, planners had to deal with the effects the car brought: pedestrian dangers, noise, and exhaust fumes.

Planners, as they are known today, did not exist at this time. Traffic engineering was not even recognized as a separate engineering discipline. Road designers, as such, worked in an emerging field of knowledge that was acquired through actual application. Only a small number of engineers understood the fundamental differences between transport planning and road construction techniques, a legacy with which many cities have had to deal during recent times. Many of these early road engineers were civil or electrical engineers self-taught in the areas of transportation planning and construction.

The U.S. Institute of Transportation Engineers (ITE) was formed in 1930, and a specialized program at Yale University was established with the aim of

. . . study and improvement of the traffic performance of road network and terminals. Its

purpose [was] to achieve efficient, free, and rapid flow of traffic . . . based on scientific and engineering disciplines.

The early papers and publications that emanated from ITE set the tone of road engineering and transportation planning from the 1940s onward, featuring efficient high-speed road networks over local residential networks.

The evolution of street patterns since 1900 shows the influence the car has had on determining the planning policies that inevitably followed. Rather than planners being proactive in accommodating the growth of motor vehicle owners, they became reactive. The demands of people wanting to live farther away from the city centers and commute into them became the defining element in the way cities expanded and grew, helped along by the inexpensive cost of gasoline.

New Designs

In the 1920s, Raymond Unwin, Thomas Adams, and Clarence Perry—the first of the suburban designers—tried to end the dominance of the grid pattern by arguing that localities should protect neighborhood living through planning measures. Some of these guiding principles were the adaptation of streets to the traffic load and type of use they would have; widths of streets being determined on their hierarchical status; landscape circles or ovals interposed at junctions to compel cautious driving; staggered cross-streets and cul-de-sacs contributing to safety, attractiveness, and variety; and, if long blocks were used, pedestrian footpaths offering shortcuts.

Radburn, New Jersey, was the first suburb to adopt these principles on the basis that the residential neighborhood as a unique identity needed to be protected and deliberately planned. Although innovative and widely accepted as a template for all suburban design, the concept was not taken onboard by the private sector. The chief obstacles to the broader acceptance of the concept were the prevailing small-scale building enterprises and the lack of comprehensive planning policies capable of implementing the concept.

Superblocks brought a new method of traffic circulation into play. Traffic would travel along wide collector roads or divided arterials with landscaped areas in the center, while people walked along

landscaped footpaths, evoking the rural setting and foot accessibility of the pre-automobile era.

As cities expanded beyond the central grid pattern either in a square or rectangular grid layout, the 1950s saw the introduction of fragmented parallel-grid patterns. These allowed for longer street lengths, which in turn led to more green spaces in terms of parks and open spaces.

As the car became ever more popular, the following decade saw a slight variation to the fragmented parallel grid pattern in the form of the warped parallel grid pattern. This allowed for a curvilinear type of road running parallel with another, offering a more pleasing aspect to traveling and breaking the typical grid pattern that existed up until then.

Loop and Cul-de-Sac Layouts

With the ever increasing influence of the motor car, adaptations to the parallel grid-pattern layout evolved. This resulted in the introduction of looped roads and cul-de-sacs for housing away from the main roads, the elimination of footpaths and park land, and more intense commercial development at the sacrifice of the overall aesthetic and pleasantness of the original model.

Developers of residential subdivisions soon preferred loops and lollipops, as well as cul-de-sac street types, rather than the parallel-grid pattern type. Although all three types are efficient in terms of traffic movement, comparable residential densities for the loop and cul-de-sac street types were more efficient in comparison to the traditional grid pattern.

This also meant more land could be built on. The fringes of the city became a series of sprawling suburbs as the rise of the motor car continued unabated in the 1970s. A by-product of the increasing areas of suburbia was the construction of freeways from the most popular areas to the city center.

With the cost of living closer to the center of a city rising year by year, the expansion into the suburbs continued unabated into the 1980s. Great swaths of land were acquired by developers and similar-looking housing estates sprang up. These estates had a sprawling street pattern that promoted a feeling of privacy with short streets in disconnected subdivisions, the “lollipop on a stick” layout.

However, this marked a turning point in the way the car had led the expansion of city planning and development. Public transport facilities had been

stretched, rather than expanded, to cope with the growth of cities and offered no viable alternative to the convenience of the car. This in turn led to the capacity of the main collector and arterial roads becoming stretched to the point where traffic congestion traveling in and out of cities during rush hour (and at other times in some cities) was a daily occurrence.

The loop and cul-de-sac street layouts evolved because of the motor car rather than as a logical planning step for all forms of transport. While cities underwent expansion during the 20th century, the availability of land, the low cost of fuel, and the local authorities' willingness to provide roads (often in conjunction with the developers) fed the expansion boom. The invention of freeways compounded the boom.

It was not until the problems of traffic congestion became commonplace that attitudes changed. Once planners and local authorities realized that if a new road or freeway were built to alleviate congestion, sooner or later these new roads would too become congested, and they began to look at ways of trying to reduce car use by financial means—parking charges, congestion charges, etc.—and encouraging people to use public transport once more.

The original gridiron layout that still existed in the center of the cities was now shown to be an inefficient carrier of motor vehicle traffic. With grid intersections offering 16 points of conflict, each intersection became a barrier to free-flowing traffic. The introduction of traffic lights brought some order to the traffic flow but introduced idling time for vehicles. This, of course, led to an increase in pollution, with traffic exhaust fumes being pumped into the streets.

These grid intersections often occurred every 200 to 250 feet (65 to 80 meters) or 7 to 9 seconds at typical car speeds, which created an obstacle to the motor car's main aim to provide a rapid form of transport. The grid, for so long the mainstay of city centers, had become an impediment to car traffic, compromising speed or safety or both. When large amounts of traffic were present, even with the introduction of traffic lights and stop signs, the end result would be gridlock.

This does not mean that the later adaptations of street patterns, most notably the loops, lollipops, and cul-de-sac patterns, were congestion free. Congestion occurs on arterial roads in the above



A loop and cul-de-sac street layout seen from above in a housing development in Las Vegas, Nevada, in 2000. Developers appreciated the residential densities allowed by such designs, but they have tended to inhibit pedestrian travel.

patterns, not by any fault of the road network, but by the segregation and concentration of similar land uses, such as shopping malls, retail parks, or office parks.

Because these patterns have been designed specifically for the car, they are not suited for pedestrian use. While cities grew to accommodate the need for more housing, and roads were built to increase the frequency of people traveling in their cars, thoughts of pedestrian usage—which was a main driver of the grid system—were very rarely entertained. The discontinuity of the loops, lollipops, and cul-de-sacs inhibit pedestrian access to the facilities and amenities easily reachable by motor vehicles, while their curviness lengthens and deters walking trips.

Street Quality Components

The quality of streets depends on both physical and operational components. These components produce an image in the pedestrian's mind of sociability, walkability, and delight, and in the driver's of ease of driving and safety.

The sociability of a street is essential to its overall quality. Residential satisfaction is reflected in the level of social interaction that takes place on a street and creates feelings of security and belonging. Street activity cannot be designed but can be encouraged by certain street characteristics. Heavy traffic would have a detrimental effect on the sociability because of its noise and pollution from exhaust fumes. If a street pattern encourages speed through widened streets, the sociability will consequently suffer. The best street patterns to offer sociability would be the discontinuous street patterns, which have a consistently lower rate of accidents and a higher level of perceived security.

Walkability by its very nature conjures up an image of comfortable access to local amenities and services. Street patterns can affect the location of these amenities but are not determined by them. Loops and lollipops and cul-de-sac street patterns do not lend themselves to walkability; these street patterns can be confusing, laborious, and discontinuous. Collector and arterial streets do not aid walkability either, because they are perceived to be inhospitable and unsafe with their high traffic volume, which naturally discourages pedestrian use.

Recent subdivisions have actually gone back to the original grid plan to create safe and more direct pedestrian routes, yet, quite often, the local amenities available to the community are beyond the acceptable five-minute walking distance preferred by people according to design guidelines. For walkability to be accepted, it requires a conducive street pattern and a reasonable arrangement of land uses.

Aesthetically, any street encouraging pedestrians along its way must be a source of delight, often meaning a street that has been pleasantly landscaped and easy to negotiate. Green space in any form is acknowledged as having social and health benefits; hence, the inclusion of green spaces in any development is further enhanced if the development is next to or close to parks or open spaces. These green spaces also become an oasis, providing safe playing spaces for children, an area for informal contacts, and a place for relaxation.

Open green space also has a beneficial environmental effect. It keeps the air cooler, retains rainwater, and recycles carbon dioxide, and is a key element of quality in any residential area or development. Residents have been known to accept an

increased density of houses so long as quality open space is provided as part of the development.

A motorist expects as much pleasure from driving as a pedestrian expects from walking. Street patterns that are usually liked by pedestrians are loathed by motorists and vice versa. For motorists, unimpeded traffic flow, perceived safety, and good visual aspects make the driving experience more pleasurable. These qualities are achieved by reducing and simplifying intersections, increasing lane widths and widening curves, and completely separating opposing streams of traffic by man-made or natural dividers. However, the road that best encapsulates these desires is the urban parkway, the least favorable to the pedestrian.

Street patterns, evolved and driven by one form of transport without taking into consideration all the various forms of transport, have led to cities becoming congested and undesirable as places to live. People who live in suburban areas are now faced with the consequences of these actions.

Retrospectively, planners are recreating livable city centers and redesigning suburbs to take into account the changing environment now being faced. Better public transport links and refurbishment of inner-city offices into apartments are just two of the many facets being considered, as well as the redesigning of street patterns to meet new requirements being demanded by the public.

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See Also: Automobile Culture; Complete Streets; Greenways; Institute of Traffic Engineers; Livable Streets; Pedestrian Safety; Public Participation in Transportation Planning; Traffic Congestion; Transit-Oriented Development; Urban Sprawl Versus Compact Development.

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Streetcars/Trolleys

Street railways were introduced first in New York in 1832, as a way of improving the productivity of horses, which provided the traction for omnibuses and coaches. On dirt roads, which in wet weather turned to mud, a horse could pull at most 10 passengers. Mounting the vehicle on smooth iron rails allowed one horse to pull 40 passengers. This reduced operating costs and allowed lower fares to attract more passengers, though still mostly wealthier residents. Horse-drawn streetcars or “horsecars” appeared in all major American and European cities by 1880.

Horses, though, fell ill and their food costs fluctuated, so various methods of mechanical traction were tried, including steam engines, compressed air, battery power, and cable haulage, of which only systems in San Francisco, California, and Llandudno, Wales, still remain in operation. The great step forward was the application of electricity via an overhead cable, powering motors. Frank Sprague demonstrated the trolley pole system of power collection in Richmond, Virginia, in 1887. Overhead wires and the practical trolley pole revolutionized the way in which streetcars could be powered.

With this new technology, and unlike horsecars, there was no practical limit to the distance that electric streetcars could operate, allowing horse streetcar lines to be extended into the growing suburbs and then enabling larger (eight-wheel) streetcars to replace small four-wheelers. Both of these further reduced operating costs and made streetcars the first mass transportation system.

Cities could now expand to house larger populations and new industries. Developers worked with streetcar companies to build new houses along extended streetcar lines, which benefited from the increase in traffic. For the first time in history, ordinary people did not have to live within walking distance of their place of work, and housing developments provided a better environment than that around inner-city factories.

Function

Streetcars also provided the means for people to reach a wider range of jobs and services than was possible when walking was the only affordable means of transportation. Early on, streetcar lines concentrated upon the twice-daily movement of

workers. Quickly, it became clear that the tidal flow of commuters presented economic problems for operators. Commuter traffic required a large number of streetcars and staff, which were not fully used outside peak hours.

More enterprising streetcar companies soon introduced measures to stimulate traffic during the off-peak times when there was spare capacity. Then the extra cost of carrying passengers was marginal. Low-price off-peak tickets, day tickets starting after the morning peak, and similar travel incentives were introduced. Some streetcar lines also carried parcels and letter boxes to give better access to the postal system and to generate additional revenue.

The function of streetcars was eroded by the advent of the motor car and the surfacing of roads. At first only the wealthy could afford cars, hardly making a difference to streetcar traffic. After 1920, when mass production brought down the cost of automobiles and new oil fields the cost of fuel, an increasing number of streetcar passengers bought cars and stopped riding streetcars.

This had two adverse effects on the finances of streetcar lines. The loss of passenger traffic and revenue to automobile trips weakened the financial position of streetcar companies, who were forced to defer maintenance or replace old streetcars with modern vehicles. The second adverse effect was the increase in traffic congestion caused by the anarchic traffic conditions created by automobile traffic. This slowed streetcars and made timetables unreliable, causing even more passengers to switch to cars.

A minor reversal was achieved by the Presidents' Conference Committee (PCC) in 1929, investing in a new and modern streetcar design to provide a better service at lower cost than old streetcars. This standard PCC streetcar was soon being built by a number of U.S. manufacturers, and by 1940 over 5,000 were in service in North America, giving a new lease on life to the remaining streetcar lines—and automobiles a run for their money.

Social Stratification

When streetcars were horsedrawn, they were the preserve of middle-income groups, who could afford to buy edge-of-town houses and pay the streetcar fares to reach their downtown offices and shops. With electrification, streetcars became the travel mode of lower-income groups, although

middle-income passengers continued to ride until they switched to automobiles.

Some streetcar systems tried offering different classes of accommodation, for example with separate “first class” cars, with upholstered seats, curtains, and ample light. Other operators set aside parts of streetcars for first class passengers, separate from the majority of passengers. By the close of World War II, however, most street railways were facing deep financial difficulties and by the 1960s most streetcars had been replaced by rubber-tired diesel buses.

The reintroduction of the streetcar in Portland, Oregon, and other cities like it has been driven as much by tourist traffic and their downtown movements as the need for a serious method of transport. Cities like Boston, Philadelphia, and Toronto that never abandoned streetcars are looking to expand and improve networks to current European practice. It is true to say that streetcars are a more widely acceptable mode of transport across income groups than buses.

Perception

Both buses and streetcars run along city streets, so why is there a difference in perception and social acceptability between them? Part of the reason is due to the quality of service provided and part to the urban fabric. By running on tracks, streetcars follow paths that have been designed to give the most comfortable ride, with gentle and controlled side jerking, for example. Streetcar drivers operate a vehicle where the dynamics are also preset to give the maximum of passenger safety and comfort. There is no known case of an automobile driver shooting a streetcar driver for getting in his way.

Another part of the difference in perception between buses and streetcars is the fact that streetcar tracks are a permanent feature of the urban infrastructure. Indeed, in some cities like Philadelphia, abandoned streetcar car routes still have the tracks in place, for example, to Germantown, and so could easily be reopened. But mainly, streetcar tracks signify that the service will be there into the future. Buses, on the other hand, are “flexible,” and users know that their routes can change or be withdrawn on short notice.

This is despite the fact that in many cities bus networks have remained static for many decades, reflecting the more glacial changes to the urban

economy and its infrastructure. But people who have cars, and therefore the ultimate flexible travel mode, ironically look for permanence in transit. One study in the United Kingdom asked respondents about their willingness to buy a house near different modes of transit for access to commuter trips to work. Well over 80 percent would buy a house near an electric rail line, about 50 percent near a nonelectric rail line, and less than 20 percent near a bus stop.

Routes

Historically, streetcar routes followed the main streets of the city that carried the most traffic. Network synergy was provided by having streetcar stops at intersection corners and by issuing transfer tickets. Those cities still operating streetcars have such operating patterns, although with routes not on each main thoroughfare, as retrenchment has led to the abandonment of less busy lines.

The function of a streetcar system is to carry passengers, and therefore serving major traffic flows makes a lot of sense. Newer streetcar lines such as those in Portland tend to provide downtown distributors, allowing tourists especially to get around the city center and to enjoy the major tourist attractions.

A new streetcar system to serve a metropolitan area should follow light rail transit (LRT) practice and seek out the routes with the densest automobile traffic. Rarely does it make sense to replace a bus line with streetcars unless the route also has heavy automobile traffic. For a metropolitan area, the designation of routes is one part of planning. The other part is the identification of optimum places for interchanges between routes, to maximize the utility of the whole network through synergy.

Historically, the downtown area of a city had the largest concentration of economic activity and employment and the densest development. Today that is not always the case, and often there is more traffic between suburbs than to the central business district (CBD). In relative terms, because the CBD is usually geographically smaller than most suburbs, serving the CBD will still be a key traffic objective.

Where new rail systems have been built in the last 20 years, often the incentive has been underused potential of the CBD, limited by available parking and the capacity of access roads. Building freeways to the CBD is expensive and often

counterproductive, whereas streetcar lines can significantly increase the passenger capacity of existing roads, without the need for demolition, and can free up CBD parking for more value-added economic activities.

Services

When passengers were captive to streetcar services, due to a lack of an alternative such as a car, the operator did not need to provide too high a quality of service, except to avoid overcrowding and passenger congestion at stops. Now most people have at least one car, which can be used whenever needed to go anywhere. So streetcar services must cater to the perception of automobile users. This can best be done by having a high-frequency service, so that passengers may “turn up and go” without having to know a timetable, and operating at a high level of reliability, so that a streetcar trip is more dependable than an auto trip.

Both of these service characteristics require a large fleet of streetcars and therefore high operating costs. However, operating costs can be reduced if operating speeds can be increased, so that fewer streetcars can make more trips. Here the cooperation of the highway authority is needed, since it makes little economic sense for a streetcar with 100 passengers to be held up at a road intersection with traffic signals to allow 10 cars with 15 passengers to cross.

Giving streetcars priority at road intersections, such as by preempting traffic signals so that streetcars can cross nonstop, can provide a significant improvement in operating speed. Similarly, in busy roads, giving streetcars exclusive lanes so they do not have to queue in congested times with other traffic also improves operating speed. Both these priority measures also feed back into improving the perception of car commuters to the benefits of using streetcars as an alternative method of getting to work.

Policy Coordination

It is clear from studies in many cities that the utility of transit investment, for example, in a streetcar line, can be increased by coordination with other land use and economic policies. Approving new higher-density developments along streetcar lines provides more potential passengers, which can then make the transit service more attractive. Allowing



A streetcar running on electricity delivered by overhead cables in Lisbon, Portugal, in 2013. One study found that more than 80 percent of people would buy a house near an electric rail line, compared to less than 20 percent near a bus stop.

commercial developments in the CBD, which has less (or no) car parking, also provides an incentive to access the completed new development by transit. This can be further enhanced if an out-of-town park-and-ride facility on the streetcar line is built, widening the CBD catchment area and enhancing the CBD environment by having less motor traffic and toxic air pollution.

Coordinating such policy initiatives can sometimes be difficult in that a streetcar line can be planned and built in under five years, whereas land use transformation can take 10 to 15 years. So how can transit and land use developments be kept synchronized? This is especially difficult if different agencies are responsible for land use development and transit. A private developer may have permission for a new downtown shopping mall

but will not start until the streetcar line is built to guarantee that customers can arrive. Then there is a dip in the economy and the retail market looks weak, so the streetcar line operates with fewer passengers and a bigger loss—should the shopping mall developer pay?

Maintenance and Repairs

Transit has to be 100 percent reliable if it is to attract and retain patronage. This means a rolling program of preventive maintenance. Streetcars can be repaired one at a time in the depot out of sight of passengers. A fleet with spare vehicles will ensure that the advertised service frequency can always be maintained.

Infrastructure is another matter. Often the track is damaged not by streetcars but by heavy road vehicles. The question is, then, how and when to repair tracks. If the damaged section is short, then one working line can be adopted, using temporary crossovers. This allows the service to operate, with hardly any impact on the passengers in terms of longer waits or rides. If the line is circular, then operation in one direction can be used while repairs are carried out. This does impose some inconvenience on passengers, from longer journeys on average to overcrowding, unless all the streetcars operate in the one direction. For a CBD-based streetcar line, the average journey will only increase by a minute or two, still much faster than walking.

For the routine replacement of worn tracks, all too often transit operators shut down the service for the duration of the replacement. With planning and careful scheduling, overnight replacement of worn tracks can allow streetcar services during the day without any interruption of service. This may cost more than closing the service and doing the repairs in one operation, but that ignores the loss of passenger goodwill and revenue.

Modal Competition/Coordination

There is no city in the world where car traffic is controlled administratively. There are examples of traffic management, either by physical measures (for example, traffic signal control, parking restrictions), or by fiscal measures (like charges to enter the CBD, or for on-street parking). Therefore, the main competitor to transit service is the private automobile. To improve transit's market share, therefore, requires competitive actions to attract some car trips.

Price is rarely the most effective way to attract auto trips, since car commuters spend a significant part of their income for the convenience and prestige of a car. In most market research exercises, service characteristics like reliability, journey speed and convenience rate more highly than transit fares as the measures needed to attract trips. Taxis, after all, are an important transport service in most cities, at fare levels much higher than transit.

Too often transit fares are set for political reasons rather than a clear assessment of market characteristics. Higher fares would allow investment in improving transit services, for example, by faster speeds, higher frequencies, and new stops more convenient for parts of the city not well served. In one study, new stops were found to give the best and biggest payback, often in a few months, by virtue of attracting passengers who previously were unable to use transit.

Competition between transit modes is rarely serious, even in cities where on-street transit competition is allowed. One example was in Sheffield, in the United Kingdom, where a company started a bus service at half the fare of the parallel streetcar line. The bus service lasted only six months and then was withdrawn for lack of bus passengers. In most cities, different modes of transit can and should be coordinated. Buses should feed and distribute rail and streetcar traffic. This is most effective with "cross platform" interchanges and through shared ticketing.

Civic Objectives

The most fundamental question over the introduction of a new streetcar line or system is what the objective to be fulfilled is. In public projects, objectives like raising profile, economic regeneration, and reducing social exclusion are often part of the rhetoric. If the capital costs and running costs are being met entirely from public funds, these can be legitimate objectives. If, however, the streetcar line is not being subsidized in its operating costs, then the attraction of passengers paying a fare must be included as an important objective. Making an assessment of the number of passengers to be carried and the fare they are willing to pay is a critical part of the calculus.

Politicians like low fares, which win votes. However, in an environment where passengers have travel options, fares may not be the most important

lever, since in most transit systems fare elasticity is usually about minus 0.3. This means that reducing fares by 10 percent increases the number of riders by only 3 percent, so the revenue is reduced by 7 percent, increasing the need for subsidy.

There is no doubt that a transit system can be a unique reflection of a city. With mega companies dominating retail and other businesses, there is a danger that cities can begin to look alike. A transit system can be a city's signature. It is therefore not surprising that in many European cities, souvenir postcards increasingly feature the local streetcars.

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See Also: Light Rail Transit; Planning, Programming, and Budgeting Systems; Tramways; Transit Corridor Planning; Transit Demographics; Transit Lines/Networks; Transit Planning, International; Transit Ridership.

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However, recent events have resulted in student safety becoming a major issue. Even in quiet neighborhoods, parents are worried that their children may be in jeopardy. It is reasonable for them to feel that way in view of school shootings, bomb threats, and the specter of domestic terrorism. Correspondingly, teachers are being trained on how to respond if the worst should happen at their school. They are told where to take the students in the event of an emergency and whom to contact. With all of the headlines about high-profile tragedies, teachers and administrators are more aware than ever of their roles in protecting students from harm during school hours.

Yet, many individuals have expressed that student transport between home neighborhoods and schools can be a weak point in the process of protecting student safety. When students as young as elementary age travel between their house and their school, there can be safety risks, which vary according to the method of student transport employed. There are also benefits to each method, which include walking, being driven by a parent or friend's parent, and riding a bus.

Walking

Children often enjoy walking to school and so have a personal motivation for doing it. They know that much of their school day will involve sitting at a desk, and walking to school gives them an opportunity to stretch their legs and expend some of their boundless youthful energy. It can also be good exercise, which is an incentive for parents to allow it.

The appropriateness of children being permitted to walk to school individually is, in part, a factor of their age. Older children are more likely than younger ones to be safety conscious along the way. That includes waiting for walk signals and looking both directions when crossing the street. Unfortunately, younger children may forget to do so. As every parent with small children knows, impulsiveness may supersede following what they have been taught about being cautious.

The same safety consideration holds true regarding strangers along the way. Older children will probably heed what their parents have told them about not talking to strangers, but younger ones may not. For these reasons, it is recommended to not let younger (or more immature) students walk to school alone.

Student Transport

In the past, teaching about safety concerns in schools was largely focused on telling students not to run in the hallways or mishandle scissors. Many communities used to feel secure that any major safety problem was improbable and could be proactively addressed by teaching good conduct to students. The biggest potential threat was fire, and so there were periodic drills to prepare for that scenario.

Even with older students, it is generally advised to have them walk to school in groups. Given that they are social creatures by nature, this will be welcomed by the students and will offer them a chance to talk with friends while in transit. If each walking group is comprised of at least five students, that will ensure that there is always a group to walk with even if one or two are home sick on a particular day. Before they first start walking together, all of their parents can go over safety rules with them. That way, they can remind each other if one forgets.

Another popular option is having a parental escort walk with the group of students each day. This underscores another good reason to have several students in a walking group, as opposed to just one or two. When you have several students, you will have at least that many parents to take turns as escorts. In neighborhoods where potential dangers are particularly concerning, having a parent provide an escort can assure the safety of all students in the group. Additionally, each parent only needs to volunteer at most one day each week for all the school days to be covered.

Of course, this requires all the parents to be willing to contribute at least some of their time to this effort. Most will be happy to, realizing that they are protecting their children and their friends. This approach to school transport has the advantage of providing safety while still allowing for the benefits of fresh air and safety. It also helps build a mutual support network among parents.

Driving and Carpooling

Especially with school safety issues in the news, many parents have decided that they must drive their children to school every day. This is perfectly reasonable and has multiple advantages. One is that it fosters a connection between parent and child at the beginning of each day, when both are fresh and wide-awake. This can be a major social benefit, with the parent and his or her daughter or son talking about the new day and what they plan to do. Some parents find this to be a good enough reason by itself to drive their children to school each day.

Safety is also a good reason. After all, a parent who drives his or her children to school does not have to worry about things going wrong in transit. They know that their child is safely delivered to the school, signed in, and securely with their teacher. Several decades ago, this might have seemed a little

overprotective, but in light of modern dangers it is perfectly sensible.

Driving their kids to school every day is not viable for every parent, however. Because of that, carpooling has become an increasingly popular option. It allows for the same high level of safety that a parent driving their own kids to school does. Just like in that case, parents know that the children are with a trusted adult between their house and school and are being kept safe and brought to their teacher. It also shares the duties among parents, just like taking turns as escorts for walking groups does. Correspondingly, a carpool group having four students will help ensure that at least one of their parents will be available to drive every day.

The Bus

There are few sights in elementary education more iconic than the big yellow school bus. If used well, it can be a secure method of student transport. One advantage is that the bus driver will probably have had a thorough background check to confirm both character and driving safety record. Parents who have any concerns can verify the background check process with their school district.

Disadvantages of riding school buses include what many people remember from their own childhood: they tend to be crowded and noisy. If the driver is the only adult on board, his or her attention will be primarily on the road. This means that the driver may not be able to address all incidents of nonconstructive conduct by students toward their peers. This can be a significant concern, especially with current awareness about the dangers of bullying.

One way to address that concern is by having schools specifically designate specific children as safety monitors. These older students, who have demonstrated their responsibility to teachers at school, can help ensure that the conduct of others is safe and healthy. If anything comes up that they cannot address with reminders to those acting out, they can inform the driver, who can talk to those having trouble. With this oversight process in place, student safety is enhanced for everyone.

Of course, even the older students can be subjected to peer pressure and may falter in their duties. For that reason, an additional safety measure on buses involves parent volunteers. These volunteers can also monitor behavior and carry more authority

than student safety monitors do. Their presence is likely to preclude not only overt bullying but also inappropriate language. They can congenially communicate the need for respect among students while serving as good examples themselves.

While those precautions help protect the safety of those on the school bus, there is still the matter of getting on and off the bus to consider. All of the considerations noted in regard to safety for walking groups apply to going to and from bus stops. If possible, children's parents can walk them to the bus stop at the beginning of each school day and meet them at the bus stop when they come home. That way, there are no periods in which the children are without a trusted adult. As with carpooling, parents can take turns doing this by forming a network with the moms and dads of their children's friends.

Taking children to and from the bus stop is one part of the equation when choosing to use buses. The other key part is making sure the children get off and on buses at school securely. Different schools may vary in their procedures for this. Some may have teachers meet buses in the morning and deliver students to buses at the end of the day. This is the safest approach, since the teachers are then able to verify each student getting on or off the bus when they should. Other schools may let students get on and off buses unescorted or have an older student in a safety monitor role during these transitions. Parents who are uncertain of how this is handled can inquire of the school and even be present when it happens to see for themselves. That way, each parent can make a decision for themselves as to whether they are comfortable with the level of safety they see. If they feel that there is insufficient organization or safety, they may want to pursue a different method of student transport for their children.

Looking Forward

All of these approaches are being looked at more closely than ever, with parents and teachers weighing the benefits of each. All of them want the students to be safe, though they may have differing opinions about how to best accomplish that. Teachers and parents who have been very involved with the school may feel that traditional buses are perfectly fine. Parents who are particularly concerned about the neighborhood or want bonding time may feel that driving their kids personally is preferable.

Still others are focused on the benefits of letting their children walk, while emphasizing the benefits of safety in numbers.

Whatever the student transport choices made by particular families, it is generally accepted that safety should always be the first priority. First and foremost, this involves ongoing conversations in each family. Those conversations include how to keep safe and act safely toward others. They also necessitate talking about potential dangers and about what to do in challenging situations.

At schools, many of the same conversations are happening in classes between students and teachers. There, the discussion includes following school procedures and policies like always, checking in with adults in charge. Parents, teachers, and children are conversing together to make sure that traveling to and from school stays a positive and safe experience for all involved.

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See Also: Carpooling; School Bus Safety; School Buses; School Transportation; University Transportation Centers; Walking.

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Subway Systems

Subways have a significant impact on the growth and success of today's cities. Subway systems in Tokyo, Seoul, Shanghai, Beijing, Moscow, London, Paris, and Tokyo have played critical roles in their economic development in recent decades. While already existing in American cities including New York, Boston, Philadelphia, Washington, D.C., and

Los Angeles, old subway systems can be revitalized or combined with new systems to stimulate economic progress. Cost, development and infrastructure problems, administration including expansion and contraction of governing authority and territory, and ridership are key issues facing subway systems worldwide, despite their history and contemporary operating procedures.

Subways in Asia

The Tokyo subway is part of a widespread rapid transit system that covers Japan's Greater Tokyo area. Although the Tokyo subway operates mostly within the central city, its lines extend onto suburban railway lines so that in 2013, the entire Tokyo Metro and Toei Subway system, had 290 stations and 13 lines, together carrying an average of over 8 million passengers a day.

The two primary subway operators in Tokyo are Tokyo Metro, formerly Teito Rapid Transit Authority, which was privatized in 2004 and operates 184 stations and nine lines. The Toei Subway, an arm of the Tokyo Metropolitan Government operating under the Tokyo Metropolitan Bureau of Transportation, operates 106 stations and four lines. They have different fare structures. Although Tokyo Metro and Toei Subway systems feature a unified system of line colors, line codes, and station numbers, they have different operating obstacles to overcome, including differences in fares and separate administrative bodies, infrastructures, and policies.

Other subway systems, including the Seoul Metropolitan System, operate under one authority but still face similar problems—like breaking even and overcrowding. Consisting of 19 lines, the Seoul Metropolitan Subway system in South Korea opened in 1974 and enables its 5.6 million daily riders to reach their destinations safely and quickly, while operating at just a minor loss. The Seoul Subway System is noted for its cleanliness, passenger-friendly features, and use of advanced technology such as Internet access, digital TV screens, automatic payment systems, and climate-controlled seats. Planners are projecting extended lines and services from 2013 to 2018, including hookups with the Incheon 2 and other lines.

In China, the state-owned Beijing Mass Transit Railway Operation Corporation, with 14 lines, and the public-private joint venture with the Hong

Kong MTR, with three lines, operate the Beijing subway, which is the oldest metro system in mainland China. The Beijing subway is the third largest in the world in annual ridership after Seoul and Moscow, with 2.46 billion trips in 2012 and an average weekly ridership of over 10 million. Beijing city planners addressed the city's ongoing traffic congestion problem by scheduling construction plans for additional lines to begin before 2015.

In 2012, Ying Minghong, board chairman of Shanghai Shentong Metro Group Co., which operates Shanghai's subway, stated in *China Daily* that Shanghai's subway system operated in the red. China's longest subway network, with 11 lines totaling more than 265 miles, the Shanghai Metro system totaled 354 miles by 2013 and is predicted to reach 544 miles by 2020. Shanghai Metro had 2.1 billion passengers in 2011, but the system does not generate enough income to be self-sustaining, even with Shanghai's 23 million population. The chairman said that ticket sales and advertising income cover daily operating costs but they do not cover maintenance or the interest on loans, emphasizing that other subway systems including the Moscow Metro had the same problem.

Russian and Western European Subways

As of 2013, the Moscow Metro operated 190 stations featuring décor illustrating Russian architecture and art along a 197.3-mile route, and carried about 6.6 million passengers a day. Citing a 2012 to 2020 time frame, the Moscow Metro plans to expand by almost 93 miles, which will make it the third-largest metro system after the Beijing and Shanghai Metro systems. According to Moscow Metro chief Dmitry Gayev, revenue from fares, the main source of income for most tube systems, accounts for up to 70 percent of all the Moscow Metro's income, with the rest coming from state subsidies and other commercial operations.

In his book *Down the Tube*, transport expert Christian Wolmar stated that with 3.5 million passenger journeys a day, the London Underground could make annual profits without capital and structural improvements, but transport companies suggest that the cost of a ticket is what makes the difference.

The London Underground system's 250 miles of track and 270 stations serve most of Greater London and parts of Buckinghamshire, Hertfordshire,

and Essex counties. It has expanded to 11 lines and carried over 1 billion passengers from 2012 to 2013. As of 2012, passenger fares covered 91 percent of operating expenses.

After Moscow, the 133-mile, 303-station Paris Metro system is Europe's largest metro system, transporting a total of 1.524 billion passengers in 2011. The Paris Metro system is one of the densest metro systems in the world, with 245 stations within 34 square miles of Paris and featuring richly decorated art nouveau stations. When the Paris Metro network reached the saturation point after World War II, the system introduced newer trains to encourage high traffic, but since then improvements have been limited because of network design and the short distances between stations.

Metro systems around the world, including Montreal, Singapore, and Tokyo, adopted the Paris Metro's successful use of rubber-tired lines, and the Paris Metro also contributed the name *Metro* to worldwide systems.

Subway Systems in the United States

As the United States becomes increasingly urbanized, with 79 percent of its population living in urban areas, subways provide an efficient way to swiftly move large numbers of people and reduce pollution and congestion. Long-established subway systems in New York; Boston; Philadelphia; Washington, D.C.; and Los Angeles face the challenges of expanding and profiting into the 21st century.

One of the world's oldest public transit systems, the New York City Transit Authority contains 209 miles of routes and in 2012 averaged over 1.65 billion rides. Measured by annual ridership, the New York City subway is the seventh-busiest rapid transit rail system in the world behind the metro subway systems in Tokyo, Seoul, Beijing, Moscow, Shanghai, and Guangzhou.

As of 2013, the New York subway was comprised of three formerly separate systems that competed with each other and finally merged. August Belmont's Interborough Rapid Transit Company and the Brooklyn Manhattan Transit Corporation were privately owned and the city of New York owned and operated the independent subway system. All three were consolidated into the New York City Board of Transportation on June 1, 1940. In 1953, the New York City Transit Authority was created as a public benefit corporation to acquire the transit

facilities and operate them for public convenience and safety. The city of New York owns the New York City Subway and leases it to the New York City Transit Authority, a subsidiary agency of the Metropolitan Transportation Authority.

The Massachusetts Bay Transportation Authority (MBTA) operates all of Boston's five major types of transit vehicles: regional (commuter) rail trains, heavy rail transit (subways and elevated trains), light rail vehicles (trolleys), electric trolleybuses, and motor buses.

The MBTA applied for some of the first federal funding for modernizing 10 mass transit stations, and since 1965 it has received over \$3.5 billion for capital improvement projects along with its yearly operating program. In 1980, the governing structure of the MBTA again restructured to meet changing needs of the system. A seven-member board of directors appointed by the governor and two additional members from outside the MBTA District, along with the secretary of transportation serving as chairman of the board comprise the MBTA's governing board. The state government pays the largest share of the annual operating deficit, with fare box revenues covering about 31 percent of the authority's annual operating expenses. Measured by daily ridership, the MBTA is America's fifth-largest mass transit system with an average weekday ridership of approximately 1.3 million passenger trips.

The Southeastern Pennsylvania Transportation Authority (SEPTA) is a metropolitan transportation authority that operates bus, subway, elevated rail, commuter rail, light rail, and electric trolley buses serving 3.9 million people in the city of Philadelphia, and in Delaware, Montgomery, Bucks, and Chester Counties. SEPTA also serves New Castle County in Delaware and Mercer County in New Jersey. SEPTA is one of the only two U.S. transit authorities that operates the five major types of transit agencies, along with the MBTA. By ridership, SEPTA is the sixth-largest rapid transit system in the United States, with 280 active stations over 450 miles of track and 196 routes. It also manages shared-ride services in Philadelphia and Americans with Disabilities Act services across the region.

In 1966, the federal government passed a bill to create the Washington Metropolitan Area Transit Authority (WMATA), covering the transit region of the District of Columbia, Virginia, and Maryland.

The WMATA administers the Washington Metro subway and also operates a Metrobus, which serves Virginia and Maryland. The Metro network includes five lines, 86 stations, and 106.3 miles of track, and had a 2012 ridership total of 280,904,200 people.

Los Angeles is another city that has adopted a transit system consisting of separate lines operated by one governing authority. Operated by the Los Angeles County Metropolitan Transportation Authority, the Los Angeles Metro Rail system consists of six lines serving 80 stations in the Los Angeles County area with a June 2012 average daily weekday ridership of 362,904 passengers. The lines include the Red and Purple subway lines. The Transportation Authority plans several extended routes for the near future.

County and regional planners cite the lack of a continuity of congressional funds and the lack of motivation to invest in publicly funded infrastructure projects as reasons for the modest number of subway systems in America. In its briefing book titled *The Transportation Planning Process: Key Issues*, the U.S. Department of Transportation offers a blueprint for subway planning and creating policy and regional planning bodies.

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See Also: Heavy Rail Transit; Regional Transit Agencies; Subways/Elevated Trains; Transit Centers.

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Subways/Elevated Trains

A subway or elevated train system is one whereby the rail service is provided on an exclusive right-of-way, fully under the control of the train operator. The first subway line was opened in London, England, in 1863. The second was opened in Budapest, Hungary, in 1896. The first subway line in North America opened in 1897 in Boston.

The logic in free market societies was that the only way to escape the congestion of city streets was to build a separate transport network at a different grade from the ground, where congested city streets were to be found. Digging underground is expensive, so the less expensive option of building above ground led to elevated railways. The earliest of these were built in New York City in 1868, Boston in 1887, Chicago in 1892, and Liverpool, England, in 1893. Most of these elevated lines were built above existing streets. Some cities, such as London, did not allow such elevated lines because most streets were narrow, and such lines did not enhance the aesthetics of the urban environment.

Role of Grade Separation

Grade separation, whether in the form of a subway, elevated railway, or sometimes both—as in the most recent London Docklands system—is to give the train operator complete control of the system. This allows faster operating speeds and high-frequency services, with as little as one-minute between trains. This gives greater passenger capacities than can be economically provided by roads. Typically, a subway or elevated line operating at two-minute intervals can carry 30,000 passengers per hour. A highway with car commuters having the same capacity would need to be 21 lanes wide in each direction.

When the public purse is funding transit and road building, then subways or elevated railways are usually the more economic option compared to highway building. This analysis ignores the disruption to the city during construction and then permanently when opened. Boston's "Big Dig" showed this on a massive scale when Interstate 93 was diverted into a tunnel nearly four miles long through the city center. It turned into the most expensive road project in the history of the United States.

For both subway and elevated systems, passenger access is the most sensitive planning and design issue, with a trade-off between the high costs of each station and the generation of passenger trips. Stations can cost as much as track tunneling costs for a subway system. There is, however, an upside to station provision, as was first discovered after the Yonge Street subway line opened in Toronto in 1954, and more recently the London Docklands line. Property values increase adjacent to subway/elevated stations, thanks to the improved access provided.

In Toronto, this led to an increase in property tax revenue, which in less than 20 years paid for the Yonge Street subway line. In London, the value of land by the yet-to-be-built Docklands line increased within three months by more than the cost of the London Docklands line. As the land was in public ownership, the net cost of the London Docklands line was remarkably low, although separated into different departmental accounts.

Markets Served

Subways (and, to a lesser extent, elevated railways) are built to serve the central business district (CBD), which has the highest concentration of economic activity in a metropolitan region. This means that the traffic on such lines is heavily peaked, with spare capacity at other times.

With the growth of leisure and tourism, this spare capacity is often put to good use by offering special tourist tickets, which are only valid after the end of the morning peak. Subway systems are usually the most easily used transit system by visitors to cities, who are not familiar with the local topology. This has been reinforced by the widespread use of schematic network maps, first introduced in London, England, in 1931. Such schematic maps make system navigation easy, as long as the name of the destination station is known.



The St. Patrick Station on the Yonge–University–Spadina line in Toronto, Canada, in 2008. After the opening of the Yonge Street line, nearby property values and resulting tax revenues increased enough to pay for the subway line in less than 20 years.

While most subway and elevated railway passengers have automobiles available, the density of the CBD may make driving to work impossible, both as road capacity is limited and parking space even more so. A study in 1963 showed that central London would have to be rebuilt on at least three levels, with roads occupying the ground, parking the next two levels, and above that the economic and other activities which presently constitute the CBD. This clearly was not realizable. So access to the CBD of London is 80 percent by rail, and only 20 percent by road. Moving one million commuters during the peak two hours by road would be impossible. This role is reinforced by park-and-ride and kiss-and-ride facilities at suburban stations.

London is a rail-dominated city, with 70 percent of all British rail trips to or in London. A similar

pattern can also be seen in the United States, where nearly 60 percent of commuter trips in New York are by rail, and nearly 70 percent of all U.S. rail trips are in New York.

The CBD is therefore the reason for subway and elevated lines in the first place, and also a mechanism for reinforcing the role of the CBD by making it the most accessible part of the metropolitan region, as the prime “central place.” Secondary urban centers are usually linked to the CBD by the subway.

The increasing density of CBD development is now threatening subways, both in terms of general overcrowding and also at specific stations. Such overcrowding can lead to temporary station closures on safety grounds. Many cities are now embarking on ambitious plans to add subway capacity, with new lines, stations and interchanges, increasing network synergy and also redundant capacity in the case of a temporary line closure.

Station Location and Access

Stations are mini central places, changing the morphology of the urban environment. Stations can therefore benefit from the activity of existing urban subcenters, or by creating new ones. This provides a unique planning opportunity for strengthening the urban economy, unlike a highway interchange, which occupies a large area and is normally not accessible to pedestrians.

Not only do new subway stations have a transport and interchange function, they are also items of architecture and public art. Where a station is integrated with an “air rights” development, the station must not be lost, like an appendix to the building above. Many new transit projects devote 1 percent of their construction budget to public art. If the architectural design of new stations is also considered public art, the impact can be much greater.

Interchange With Other Modes

Because of the high cost of construction and the need for high passenger flows, a network of subway or elevated rail lines will not provide comprehensive coverage across the whole of a metropolitan area. Therefore, with the limited geographical coverage possible from a limited number of lines and stations, it will be possible to attract only a small part of the metropolitan population living within walking distance. In order to provide a greater economic and social utility, some of the stations will

need to be configured to make interchange with other modes easy, especially car and bus.

Such interchange stations will normally be at or near the outer edge of the metropolitan area, so that most of the journey is made on the rail line. “Feeder” trips by car and bus will be short, both in distance and time. To make these interchange trips highly attractive will require the physical design of the interchange to be as convenient as possible. There are now plenty of examples in the United States and Europe to avoid the pitfalls and reap the benefits from successful designs.

For bus and ride passengers, the ideal is “cross platform,” with a timed connection, so there is no waiting. There may also be scope for bike and ride interchange. At many European stations, hundreds of bikes are parked. Indeed, in some places, commuters have two bikes, one at the home end and another at the work end, for two bike rides with a rail ride in between.

Park-and-Ride or Kiss-and-Ride

In most developed countries the main feeder mode to interchange stations will be the private automobile, justifying a section in its own right. There are two ways in which this works. The majority of trips will involve the driver parking a car and riding the rail line. There will also be trips where the commuter is dropped off (kiss-and-ride), and the car driven away for use during the day, such as taking children to school.

Kiss-and-ride requirements should have the drop-off and pickup points close to the platform, for a minimum walk. Although commuters tend to go for a particular train, arrivals will be on a skewed distribution, before train departure, unless the service is very frequent (under five-minute intervals), when arrivals will be almost random. There should be space for about 10 cars at a time for drop-off, and the exit route should be clear and short to minimize the occupation and congestion of the interchange station area. The circulation of kiss-and-ride traffic should be separate from park-and-ride.

For park-and-riders, those who arrive earliest will park nearest the platform, so they have the shortest walk. In any case, there need to be clear and direct foot routes from all parts of the parking lot to the rail platform. Depending on the local weather and climate, these routes may also need to be protected from wind, sun, and rain.

Some park-and-ride interchange stations are also used informally by carpoolers. Three of four commuters drive to the interchange and share one car to work. While this does not provide any riders for the rail line, it does reduce the number of cars on congested roads, and the poolers may take advantage of high occupancy vehicle (HOV) freeway lanes. If the interchange is operating near capacity, this car-sharing use reduces the chance to increase transit use. How this is addressed will usually be a local solution. One solution is to charge for parking with a free transit return ride.

Air Rights Development

Subway stations are often constructed by “cut and cove” methods, resulting in the space over the station being available for other developments. Selling the air rights to high added-value activity uses will help to offset some of the construction costs. Other sub-surface parts of a subway line may not be in tunnel but cutting. Again there is an opportunity to exploit these spaces, but for lower-level activities, unless very near a subway station. In constructing a new line, such air rights developments can be integrated into the subway construction. When the Hong Kong subway was built, even the train depot air rights were exploited for high-rise apartments. Elevated lines rarely lend themselves to air rights developments, but may have spaces under the structure that can be used for ancillary economic activities.

Impact on Urban Economy

As many studies have shown, a subway can have secondary economic benefits for the metropolitan area many times greater than the cost of building the subway. Unfortunately, these benefits can rarely be captured directly by the subway builder.

In Toronto, after the first subway (the Yonge Street line) opened, real estate development around the stations recouped the investment in the line. Various proposals for “value recapture taxes” have been made but none so far have been implemented. Second best, then, is the rise in property values, and so local property tax revenues.

There are, however, other benefits. These include the stimulation of the CBD as an employment center and the multiplier effect that has throughout the metropolitan region—for example, by boosting local service and retail businesses in residential areas where CBD commuters live.

Social and Other Effects

Car commuting is inherently an unsocial activity. If a commuter has a family at one end and work at the other, there is a lack of social interaction during the journey to and from work, even including sharing gestures while crawling along a congested freeway. Transit can be a very sociable activity and certainly provides opportunity for informal friendships. This is especially true for regular commuters who graduate from eye contact, to smiles, greetings, conversations, and more involved interactions.

Studies have also shown that rail transit riders are usually healthier than car commuters. This is directly a result of regular exercise, even if only walking across a park-and-ride lot at one end of the trip and from the station to work at the other. Rail commuters are fitter than auto commuters, having a lower body mass index (BMI). There are also secondary benefits from reduced traffic and pollution. Transit commuters are also less likely to be killed or injured in auto crashes.

Improving rail transit can be one of the most cost-effective ways to improve public health, the tertiary benefits of which are a reduction in toxic air pollution and therefore a reduction in smog and cardio-respiratory diseases. This means less hospitalization and medication. Families could realize private economic benefits from released personal income, which can be used for other household consumption, further stimulating the local economy.

Policy

While a subway or elevated railway at its most basic is purely a mode of transport, it can also be used as an instrument of policy. Providing an alternative to auto commuting reduces traffic congestion and pressure to build more roads. Less auto traffic means less fuel consumed and less pollution created. Less pollution means less illness and death caused. In the United Kingdom, traffic pollution causes about 45,000 deaths per year. On the same basis, about a quarter of a million people in the United States are killed by toxic traffic emissions, about four times more than killed in auto crashes and firearms combined.

Subways can also be used to stimulate the local economy by strengthening the CBD, by releasing surface car parking for economic activities, and by prompting denser development that a transit service can support. Not only does this relate to

the CBD but also to each subway station, located at suitable central places, where similar land use intensification can occur.

Finally, a subway can be part of a health promotion package by encouraging people to walk, even if only across a park-and-ride lot. Additional exercise improves fitness and reduces obesity. Walking is also a good psychological stimulus. Also, the more sociable subway means there are more personal interactions and therefore the chance of better social influences.

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See Also: Park-and-Ride/Kiss-and-Ride Lots; Public Transit Employees and Labor Issues; Subway Systems.

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Sulfur Dioxide

A noxious, poisonous gas with a strongly acrid smell, sulfur dioxide is a chemical compound that can originate from both natural and (human-made) anthropogenic sources. One of the sulfur oxides (SO_x) formed by the interaction of sulfur and oxygen, sulfur dioxide is also referred to as sulfurous anhydride and has the formula SO_2 . It may eventually be converted to the highly corrosive sulfuric acid (with a formula of H_2SO_4).

A colorless gas, SO_2 is an air pollutant with health risks for both humans and animals. Sulfur dioxide in the atmosphere contributes to smog formation, as well as acid rain. Additionally, it can negatively affect vegetation and damage structures. Therefore, efforts have been made to reduce the amount of SO_2 in the atmosphere. Despite the adverse effects associated with SO_2 , the gas also

has beneficial uses in industry, though not without controversy. It is, for example, used in the food and beverage industries, where it is utilized as a preservative for fruit, specifically to prevent fruits from becoming discolored and brown. The beer and wine industries also employ the use of SO_2 as a preservative. Additionally, it can be used to bleach materials such as paper and fabrics. It has also been used in wastewater treatment.

Sulfur dioxide impairs breathing function in humans. Upon inhalation, it acts to constrict the bronchi (passages that convey air into the lungs), resulting in chest tightness and shortness of breath. It may also form particulates (discrete matter in liquid or solid form) when it interacts with other atmospheric components. Such small particulates ($< 2.5 \mu\text{m}$) present increased health risks. They may be inhaled and, due to their minute size, become lodged deeply inside lungs, where they restrict lung function.

While everyone is subject to the dangers of inhaling both SO_2 and sulfur-based particulate matter, some populations are especially vulnerable. Asthmatics, sufferers of bronchitis, emphysema, and heart disease, along with young children and the elderly, are particularly sensitive to damage from SO_2 . Lung function in the presence of SO_2 is made worse when breathing is predominantly done through the mouth, as often occurs during exercise.

Various organizations, such as the U.S. Environmental Protection Agency (EPA) and the World Health Organization (WHO), have issued guidelines reflecting unsafe concentrations of SO_2 in the atmosphere. These limits are used to indicate air quality by describing when air pollution (by constituent) can be assumed to result in health consequences.

The WHO revised air pollution guidelines, including those for SO_2 . Concentrations should not exceed $20 \mu\text{g}/\text{m}^3$ based on a 24-mean (or $500 \mu\text{g}/\text{m}^3$ based on a 10-minute mean), reflecting new information on the health impacts of SO_2 inhalation. The EPA, based on the Clean Air Act, sets levels of permissible concentrations for a given set of atmospheric pollutants; these include SO_2 , which is defined as a primary standard (because of its damaging effects on human health). The National Ambient Air Quality Standards (NAAQS) lists this level as 75 parts per billion by volume (ppb) for a one-hour averaging period. A secondary standard of 0.5 parts per million by volume (ppm) is designed

to protect humans indirectly (by protecting flora, fauna, and built structures); this standard utilizes a three-hour averaging time.

The largest and most important natural source of SO_2 is volcanoes. When volcanoes erupt, they release a number of gases along with solid, discrete particles, called tephra. Sulfur dioxide is one of the most abundant gases released during an eruption, after water vapor (H_2O) and carbon dioxide (CO_2). Other natural sources of SO_2 include the decomposition of vegetation in wetlands or oceans.

Wildfires can also release this gas into the atmosphere, although wildfires can be caused both naturally and anthropogenically. The amount of naturally occurring SO_2 is, however, greatly overshadowed by that entering the atmosphere through human activities. Therefore, any conversation about reducing the amount of this toxic gas in the atmosphere requires an examination of human-induced sources.

Industrial power plants that burn fossil fuels (i.e., coal) are the largest anthropogenic emitters of SO_2 to the ambient atmosphere, contributing over 60 percent in the United States. Coal contains sulfur. Therefore, an electricity generation plant that is fired by coal emits that sulfur into the air. The sulfur then reacts with oxygen, which comprises approximately 21 percent of air by volume. The result is the formation of SO_2 . Additional human-caused sulfur sources include heating of homes (with coal or oil), output from nonferrous smelters, paper manufacturing, and emissions from motor vehicles. Sulfur emissions into the atmosphere are related to both the levels of development and the populations of countries. More developed societies may generate more emissions, but they also have the wealth necessary to use mitigation technologies.

Sulfur dioxide contributes to the formation of a type of air pollution referred to as industrial or sulfur smog (not to be confused with photochemical smog). Industrial smog is primarily soot based and develops when a large amount of sulfur-containing coal is burned. This in turn interacts with fog to form a brownish-yellowish haze dangerous to humans. Indeed, this type of smog was responsible for the deaths of over 4,000 Londoners in the Great Smog of 1952. The Killer Fog of 1948 in Donora, Pennsylvania, was also attributed to SO_2 emissions from a proximate steel plant. Industrial smog is not a new problem, having been described for several centuries.



Sulfur dioxide erupting from Mount Kilauea in Hawai'i Volcanoes National Park in 2008. Volcanoes are the largest and most important natural source of SO_2 , which is the third most abundant gas released by eruptions after water vapor and carbon dioxide.

Acid Rain

One of the best-known consequences of atmospheric SO_2 is acid rain, discovered and named in 1872 by the Scottish chemist Robert Angus Smith, who worked in Manchester, England, at the time. Otherwise known as acid precipitation or acid deposition, the problem received much greater exposure in the 1960s after Svante Odén argued that industrial activity from other locations, specifically West Germany and the United Kingdom, were to blame for the deterioration of Swedish lakes.

Acid rain refers to precipitation that has a lower pH than 5.6, the approximate level of unpolluted rainwater. Typical rainwater is mildly acidic (from atmospheric CO_2 that dissolves in water, forming a weak carbonic acid). However, it can be rendered more strongly acidic by other components in the air, chiefly SO_2 and nitrogen oxide (NO).

When SO_2 emissions enter the atmosphere (largely from coal-fired power plants), they can react with various compounds. They interact with

highly reactive hydroxyl radicals (OH) and oxygen, ultimately being converted into sulfuric acid. This acid is then precipitated out of the atmosphere by rain, snow, or fog, a process called wet deposition. However, acids can be removed from the atmosphere via dry deposition, in which dry particles or aerosols, such as dust, act as carriers and bring acid to the Earth's surface. Acid rain, then, results in damage to both the natural and built environments.

Forests suffer, because acid rain weakens trees and the increasingly acidified soil provides fewer nutrients. Forest dieback (or forest decline) refers to the deterioration and death of trees (both of single or multiple species) and has been linked, at least partially, to acid rain and emissions of SO₂. Aquatic environments are particularly affected by the adverse effects of acid rain. Fish populations decrease because of fish kills, and surviving fish may have reduced body weights. Acid rain also impacts buildings, as materials such as limestone and marble become worn away at faster rates under the presence of acids. Sulfate particles associated with acid rain also contribute to reduced visibilities.

Emissions

Although SO₂ emissions lead to acid rain, the devastating effects are often felt far from the original sources of pollution. This is due to atmospheric transport of the gas and the particulates generated by its interactions with other compounds. Globally, SO₂ emissions have dropped, though there are regional differences. In both North America and Europe, for example, emissions have decreased, whereas they are rising in other places (for example, India). This diminishment is a result of various strategies employed to reduce the amount of SO₂ emitted into the atmosphere, such as utilizing natural gas (which contains much less sulfur than coal).

Another technique used to lessen emissions is the employment of scrubbers, which remove SO₂ before it is released into the air. This process, called flue-gas desulfurization, uses some alkaline material to remove the acidic SO₂ from the effluent of a smokestack. Scrubbers used in flue-gas desulfurization can be either wet or dry. Wet scrubbers employ liquids to remove the offending compounds (for example, SO₂) from a gas stream. Liquid droplets of a sorbent material absorb the SO₂, which is then treated to take out the pollutant. Spray drying is a method of desulfurization that also utilizes

liquid to extract SO₂; however, the liquid is heated and results in a powder.

Within the climate system, SO₂ has a cooling effect. Sulfate particles reflect solar radiation, preventing that energy from being absorbed and increasing temperatures. Volcanic eruptions high in sulfurous gases tend to cool the Earth's temperature, although the effect is generally small and short-lived (typically not longer than two or three years).

Historically, motor vehicle emissions contributed substantial amounts of SO₂ to the ambient atmosphere, particularly from diesel engines. Sulfur dioxide is emitted as a waste product of fossil fuel combustion. However, newer vehicles burn fuels considerably more efficiently and cleaner, thus adding fewer pollutants to the air than previously. Additionally, low-sulfur fuels, such as ultra-low-sulfur diesel (ULSD), are increasingly available to motorists, resulting in a decrease in SO₂ emissions. This fuel has greatly reduced amounts of sulfur but also produces lower fuel economy (a result of sulfur removal processes). Still, it is the predominant form of diesel fuel in Europe, North America, Australia, and New Zealand. Some countries (for example, China) have stricter sulfur limits in certain urban areas.

Ultra-low-sulfur diesel reduces emissions to the ambient atmosphere. Catalytic converters were introduced to vehicle manufacture to reduce air pollution from fuel combustion. Although vehicles may be equipped with these devices to make emissions less toxic, the converters focus on carbon monoxide (CO), nitrogen oxides (NO_x), and unburned fuel, rather than on sulfur.

Indeed, any sulfur in a fuel may oxidize to SO₂ in the conversion process. Therefore, utilization of fuels with reduced sulfur content is needed to minimize SO₂ emissions. Because the removal of sulfur is a costly process, urbanized areas in developing countries are particularly susceptible to the damage caused by SO₂ in the air.

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See Also: Air Pollution/Air Quality; Carbon Dioxide Emissions; Carbon Monoxide Emissions; Clean Air Act and Amendments; Gasoline, Reformulated; Nitrogen Oxides; Vehicle Emissions Standards; Volatile Organic Compounds.

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Supernetworks

A supernetwork represents a network consisting of flows, links, and nodes that operate over and above existing networks. Such supernetworks undergird societies and their economies, affecting a variety of economic and social activities, chiefly those related to communication, energy, and transportation. Supernetworks are studied in a variety of related and overlapping disciplines, including economics, environmental studies, finance, logistics, telecommunications, and transportation.

Transportation networks permit individuals and organizations to conduct business operations across a wider spectrum than would otherwise be the case, while also allowing individuals to keep in touch with family and friends who may live a distance away. Transportation supernetworks have evolved from the formal study of the nodes, links, and flows involved in efficient network operations. The study of supernetworks and the modeling of more efficient ways to facilitate transportation permit better organized movement of humans, information, capital, and materials over space and time.

Background

Modern transportation networks come in a variety of forms, including roadways, rail, water, and air. Even in ancient times, however, transportation networks were often a topic of consideration. At one point, for example, the ancient Romans found their

roads overwhelmed by chariots and other users. In an effort to reduce traffic congestion, Rome's leaders instituted a time-of-day chariot policy, which prohibited chariots from using Roman streets during certain hours.

As the centuries passed and transportation grew more complex and complicated, examinations of its networks grew more sophisticated and interdisciplinary, as well. Scientific techniques and procedures have been borrowed from a variety of other disciplines, including biology, computer science, engineering, finance, and mathematics. These diverse influences feed the study of transportation supernetworks with dual outlooks, which combine both management and research goals and objectives.

Models and tools that have been developed with regard to transportation supernetworks are used by businesses, government agencies, and industrial groups to better design and implement ways to transport materials, goods, and people over large and small distances.

The formal study of supernetworks initially involved the development of quantitative models that represented nodes, links, and flows as mathematical equations. Over time, this evolved to include qualitative models, with a push to design algorithms that would solve the ensuing models efficiently and successfully.

Traditional problems that those studying supernetworks examined included shortest-path, maximum-flow, and minimum-cost-flow problems. Shortest-path problems involved determining the most efficient and cost-effective path from an origin node to a destination node. Maximum-flow problems entailed determining the greatest flow that could be sent from the origin node to a destination node without exceeding the maximum capacity of the links. Minimum-cost-flow problems required a balancing of both the costs and capacities associated with the links, so that supplies at the origin nodes could be shipped at minimal costs via the links without surpassing arc capacities.

Today, those who study supernetworks consider problems and issues that have changed little over the centuries, although the technology that permits transportation has changed dramatically. The problems and issues that supernetworks work to ameliorate include congestion, system and user optimization, operations, and network interactions.

Applications

The study of network systems known as supernetworks involves the interdisciplinary analysis of the complex interactions in and between economic, environmental, financial, knowledge-flow, public utility, social, supply chain, telecommunication, and transportation networks. Researchers construct mathematical models and computer algorithms that assist optimizing flows of resources and increasing efficiency with regard to transportation supernetworks.

Congestion, for example, greatly adds to the costs and reduces the efficiency of transportation globally. In the United States and Europe, congestion—crowding of the roads, tracks, waterways, or airports that delays flow—costs organizations and consumers well over \$250 billion per year in lost productivity. As the number of automobiles continues to multiply, supernetworks that can prevent impending gridlock on roadways can prove highly beneficial. To that end, researchers work in the modeling of congestion, as well as the development of appropriate policies for congestion containment, reduction, and management.

System and user optimization are also of interest within supernetworks. System optimization, which benefits society as a whole, may look very different from user optimization, which helps an individual traveler. This disparity exists because when selecting their routes and times of travel, users inevitably select the route and time of travel based almost solely upon a desire to reduce their own travel cost or time. These outcomes may differ from those of the system, which seeks societal goals.

As the system often has control over the flows of the network, it seeks to minimize the total cost in the network and thus reduce lost productivity as much as possible. Supernetworks, thus, are enmeshed in this noncooperation between system and users, and researchers investigate ways to maximize efficiency and minimize costs.

Actual results often differ from projections, however, a phenomenon known as the Braess paradox. This paradox, named after German researcher Dietrich Braess, explores how the addition of an additional link can sometimes result in a worsening of traffic flow, in contrast to what most models predicted. Conversely, the subtraction of an existing link can sometimes improve traffic flow rather than create the gridlock expected. The Braess paradox

assumes that the underlying behavioral principle is user optimization, and shows the necessity of planning and testing models before implementing changes in the transportation network.

Supernetworks are also greatly intertwined with operations, made more difficult because of the large-scale nature and complexity of many transportation networks. The underlying network topology can vary greatly from network to network. The model used by the regional Chicago transportation network, for example, consists of nearly 13,000 nodes, over 39,000 links, and nearly 2.3 million origin/destination (OD) pairs. In contrast, the Southern California Association of Governments' model identifies 3,200 OD pairs, over 25,000 nodes, and over 99,000 links, in addition to six distinct classifications of users. Policies and procedures related to operations vary dramatically based upon which model is selected, so this choice is of keen interest to researchers of supernetworks.

Network interactions also affect transportation supernetworks. The increasing use of electronic commerce (e-commerce), for example, reduced somewhat the number of consumers using transportation networks because they were able to conduct certain shopping at home or at work. Despite this, the escalating number of goods ordered online required transport and delivery and increased demands on the transportation network, while also greatly increasing strain on the telecommunications network.

Most transportation decisions also greatly impact the environment, as over 15 percent of global carbon dioxide (CO₂) emissions are produced by motor vehicles, as are 50 percent of nitrogen dioxide and 90 percent of carbon monoxide (CO) emissions. As more citizens of the world's developing nations embrace motor vehicles as part of their transportation networks, the sustainability of the current transportation infrastructure has been questioned. As a result, discussions regarding transportation supernetworks have had to consider the costs of pollution abatement and reduction when making plans for future development and expansion.

Conclusion

Network efficiency and performance studies must examine many aspects of transportation to assure that supernetworks operate as effectively as possible. Traffic flow involves the complex interaction between

drivers, commuters, the supply chain of goods transportation, and the interaction among numerous other supernetworks, such as those involving power, telecommunications, and other components that make up our transportation infrastructure.

Because the failure of one link can have profound effects upon the entire supernetwork's performance, identifying critical links and nodes becomes a task of paramount importance. As information has grown to be an increasingly important aspect of today's economy, the creation of new knowledge regarding the functioning and operation of transportation supernetworks has become of paramount importance.

In an era of growing international competition, some nations have chosen to focus upon those transportation supernetworks that are the most technologically advanced, acting on the belief that they require intensive development of knowledge, which is something that competitors would find difficult to replicate or underprice. As a result, transportation supernetworks are often intertwined with telecommunications supernetworks, as distance—a key barrier to transportation—can often be circumvented with telecommunications savvy. As research related to transportation supernetworks continues, additional models that make use of knowledge from different but related fields will undoubtedly gain credibility and influence.

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See Also: Activity-Based Models; Freight Transport Models; Mode Choice Models; Network Modeling; Traffic Impact Assessments.

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Supply-Chain Management

A supply chain is a network that comprises every process and every party involved in the creation of goods, from before they are manufactured through to their final delivery to and purchase by the customer. Supply chains include the acquisition of materials, manufacturing, moving, and handling of goods from their source (the original supplier) to the end user or customer.

Every step in this chain involves some sort of intervention, which means that every step involves the potential to incur additional costs that the user eventually pays for at the end of the chain. Because the ability to pass goods along the supply chain most effectively will reduce the final price to the end customer—and/or increase profit for the supplier—the ability to manage the transportation actions with efficiency puts money in someone's pocket. Thus, effective supply-chain management is the ability to ensure that every step in the process is carried out as efficiently as possible, including all aspects of the transportation that occurs in the process.

The formal concepts of supply chains and supply chain management are of relatively recent origin, although in practice they have existed, albeit in a primitive form, since the 1960s. The name and formal definitions date from the 1980s but they were not widely used until the 1990s. Supply-chain management is not only now widely accepted, but it also forms the basis of an academic discipline (and degree programs with that concentration) and a lively community of organizations that seeks to define best practices and standards.

Although there has not been a great deal of activity in the study of supply chains as a serious academic discipline, that situation is gradually changing, as there has been an increase in articles addressing supply chains and their management, and scholarly books are beginning to appear, as well.

What made the introduction of supply chains and their management significant was the view of looking at an entire cycle of development and delivery that focused on an overall process with many players rather than from a single industry or participant perspective. As an overall concept, supply-chain management includes the management, oversight, communication, and planning required at every step of this complex process.

A major factor in the complexity of managing the supply chain is the potentially large number of processes: finding and getting resources, transporting them to a manufacturer or other value-add organization, the manufacture or crafting process, transportation to distributors—sometimes on an international basis—and eventual delivery to the customer. It can involve many suppliers, both of raw materials and manufactured components that make up the finished product, government agencies both domestic and international, and commercial distributors. One factor to be closely monitored by managers is that there is potential for a large number of participants, each of whom seeks to maximize its profits at its touch point, to add small extra costs along the way that will eventually add up to a large increase in the total cost to the customer.

As supply chains have become more widely used, specific applications have been developed to support the process, and third-party organizations have appeared to perform specific parts of the chain, providing managers with the ability to access support without having it as an integral part of their organizations.

The flow of materials and manufactured goods at various stages needs to be monitored using a system similar to “just-in-time” inventory because backlogs, a lack of supplies, or an interruption of the flow at some point can result in increased costs. Supply chains, to be effectively managed, must first be understood. Although different models emphasize particular aspects and have a certain degree of variance, the supply chain basically has three main components. These are the product and all processes that support its manufacture and delivery, the information that passes among all participants, and the flow of money and financial information.

Models

While there are differences in all supply chains, models have been developed to capture the salient

points of how certain models work. Some of these are developed from the perspective of the entire process, while others capture what happens before a certain point (upstream models), in the flow, or after a certain point (downstream models).

Models not only furnish a means of describing how the process flows but also provide supply-chain managers at each stage with the means to gauge progress through performance measurements. Models currently in use include the supply-chain operations reference model (SCOR), which is widely used and considered by some to be the standard means of measuring performance.

Another model is the American Productivity and Quality Center’s (APQC’s) Process Classification Framework (PCF), which is based on a high-level examination of processes. PCF is agnostic to the industry or product that is moved through the chain and is used to measure only the effectiveness of the movement of resources, products, or information. A third model is one that has been devised by the Global Supply Chain Forum, which also emphasizes all functions performed in each stage of the process, regardless of the products developed and transported to the ultimate end user.

In managing the supply-chain process, managers must consider how they will address several areas, which include how supplies and goods are actually transported and stored (that is, transportation and storage networks) and how supplies and goods will be distributed and by which modes of transportation. Additional aspects to consider are trade-offs that affect costs, especially transportation, information flows, inventory management, and financial transactions. One means to increase the effectiveness of coordination and also keep costs down is to not only coordinate activities but also create an information network in which the different parties become aware of the fact that keeping their costs as low as possible benefits everyone in the supply chain as a whole.

Globalization

One aspect of the supply chain and managing it is that in an era of increased globalization, differences among business entities that include cultural differences will probably tend to diminish. There will be a greater degree of standardization resulting in more predictability. At the same time, global supply chains will require additional security

considerations, especially in the political environment since the terrorist attacks on September 11, 2001. The United States has increased regulations in this area, and IT service management industry standards such as ISO/IEC 28000 and ISO/IEC 28001 have been published.

Another aspect of globalization is the increased pressure by nongovernmental organizations to ensure that supplies do not support the violation of good environmental standards, human rights, and fair labor practices. These, as well as other factors, may tend to complicate all aspects of the supply chain, including transportation. Also, the increased globalization will tend to complicate transportation issues, especially because of long lead times and the complex nature of international travel over long distances. Despite all of these factors, compounded by the fact that not all participants may be able to effectively deal with resultant complications, rapid improvements in information technology are beginning to mitigate these issues somewhat by increasing flow of information.

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See Also: Information Technologies and Transportation; Freight Transport, Intermodal and Multimodal; Freight Transport, Security Issues; Globalization; Transportation Economics of.

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Surface Transportation Assistance Acts of 1978 and 1982

In 1978, the Surface Transportation Assistance Act was introduced in the House of Representatives by James Howard (D-NJ). HR 95-599 was signed into law (P.L. 95-599) by President Jimmy Carter on November 6, 1978. The chief purpose of the bill was to authorize \$51.4 billion in appropriations for making highway transportation safer and improving mass transit and interstate travel in both urban and rural areas.

The bill allotted funding for fiscal years 1979 through 1982, appropriating \$30.6 billion for highways, \$7.2 billion for improving highway safety, and \$13.6 billion for public transportation. It was the first time in U.S. history that Congress had authorized federal support for mass transit and highways in a single bill.

The act also amended Title I of the Federal-Aid Highway Act of 1956 by allotting federal funds amounting to no more than 70 percent of the cost of construction of new interstates and resurfacing of interstate highways that had been constructed more than five years previously. As the appropriation period authorized by the 1978 bill neared expiration, despite considerable controversy, Congress passed the Surface Transportation Assistance Act of 1982 at the urging of President Ronald Reagan.

Responding to mounting safety and environmental concerns, the Surface Transportation Assistance Act of 1982 required states to reduce highway speeds to 55 miles per hour (mph), which cut down on both fuel usage and air pollution. States that did not enforce the 55 mph federal speed limit could expect to suffer financially. Initially, federal highway funds would be cut 5 percent. If the problem exacerbated to the point that more than 70 percent of drivers within a state were speeding, the state could lose up to 70 percent of its allotted highway funding. The act also

stipulated that an environmental impact statement be submitted by fall 1983.

The 1978 Bill

Support for mass transit was an important element in the Surface Transportation Assistance Act of 1978, and Congress authorized \$15.6 million to improve mass transit. The act amended the Emergency Highway Energy Conservation Act by providing funds for carpool projects as an energy-saving measure as long as they had no negative impact on mass transit. An additional \$7.4 billion was set aside for discretionary grants to be distributed by the secretary of transportation. Grants to states included funding for programs designated for conserving motor fuels and decreasing traffic congestion. Another provision of the bill banned the operation of any state-owned service station on interstate highways.

As a result of the 1973 oil crisis brought on by the Arab oil embargo, which precipitated a steep rise in oil prices and long lines at gas pumps, many Americans turned to biking. Even though the crisis was over by 1978, biking continued to be popular because it was good exercise and was much better for the environment than burning fossil fuels. The act supported the use of bikes by appropriating \$80 million for biking projects, although Carter neglected to include those funds in his annual budgets.

Fighting back against America's dependence on foreign oil and other imports, Congress and state legislatures began passing a series of "Buy American" laws in the 1970s that placed limits on the purchase of foreign goods. Echoing the language of the first "Buy American" act passed in 1933, during the Great Depression, the Surface Transportation Act of 1978 carried a "Buy American" provision, stipulating that transit vehicles purchased by cities qualified for federal aid only if they were assembled within the United States and if no more than half of vehicle components were manufactured outside the country.

Canadian companies, which regularly provided items such as transit vehicles and highway bridge components to the United States, may have suffered more from "Buy American" laws than any other country, losing out on billions of dollars in contracts. It was estimated that Canada was prevented from making some \$50 billion on mass transit projects authorized by the Surface Transportation Act

of 1978. Some Canadian companies responded by building plants in the United States.

The 1982 Bill

The United States experienced a severe recession in the early 1980s, and Congress was forced to deal with pressure from all sides as it addressed the economy within the context of what came to be known as Reaganomics, coupled with a trend toward returning power to state and local governments.

One of the major issues facing Congress was authorizing funds for transportation, because funding allotted under the 1978 bill was set to expire. However, the Surface Transportation Act of 1982 (HR 6211) did not sail through Congress. Instead, it faced a series of filibusters from conservative senators. Some Republicans, however, were furious over the lack of support for the president's version of the bill. Many Democrats wanted funding for public works projects included in the bill, and some wanted any taxes included in the bill levied against the wealthiest Americans, rather than average consumers.

Once cloture was invoked to end the filibusters and bring the bill to the floor for debate, according to Reagan's demands, a conference committee hurriedly worked out the differences. As a means of funding highway and mass transportation projects similar to those included in the 1978 bill, the final version of the 1982 bill provided for raising \$5.5 billion in fees from highway users.

The Surface Transportation Assistance Act of 1982 also included a small bonus for consumers. The price of tires declined because the 5-cents-a-gallon excise tax shifted the tax to gasoline and diesel fuel. Since the tax was imposed at the refinery, the impact on consumers was predicted to be less noticeable. Because heavy trucks put more wear and tear on highways, the 1982 bill established an increase in usage fees, amounting to approximately \$2,200 annually, for 18-wheelers. Trucking companies benefited, however, from provisions that allowed trucks to be wider and permitted them to carry heavier loads.

The final version of the Surface Transportation Assistance Act of 1982 was harshly criticized throughout the United States. Even many conservatives were upset because the bill allowed the federal government to continue playing a major role in transportation areas that they had hoped would be turned over to states. Environmentalists were up in

arms because they felt that the bill gutted previously established environmental protection measures.

Upon signing the 1982 bill into law, Reagan noted that the bill provided funding for 4,000 miles of interstate highways that were in need of resurfacing and for 23,000 bridges that required repair or replacement. The average cost to consumers was estimated at approximately \$30 a year. Overall, passage of the bill was considered a major victory for Reagan.

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See Also: Energy Policy and Conservation Act of 1975; Environmental Quality Improvement Act of 1970; National Mass Transportation Assistance Legislation.

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water, and pipelines. The system includes many thousands of independent yet tightly connected operators of all sizes, in both the public and private sectors. The smooth operation of the U.S. surface transportation system is essential to the country's economic strength, security, and quality of life.

The Surface Transportation Board (STB) was established in January 1996 as a successor agency to the U.S. Interstate Commerce Commission (ICC) as part of the Interstate Commerce Commission Termination Act of 1995. The bill abolished the ICC and either dissolved or dispersed its responsibilities to other regulatory bodies operating under the U.S. Department of Transportation (DOT), including the STB, the Federal Motor Carrier Safety Administration, and the Bureau of Transportation Statistics.

The STB's primary goal is to provide an efficient and effective forum for the resolution of surface transportation disputes. While falling administratively under the DOT, the STB maintains decisional autonomy regarding regulation and adjudication of matters related to freight railroads, as well as certain issues involving pipeline carriers, trucking companies engaged in collective activities, moving van companies, intercity passenger buses, and water carriers engaged in trade with Alaska, Hawai'i, or noncontiguous U.S. territories or possessions. The STB also has limited regulatory authority over the National Railroad Passenger Corporation (Amtrak).

Structure of the Organization

The STB is based in Washington, D.C., and is led by three key board members who are appointed by presidential nomination and Senate confirmation. Each senior leader is placed with the organization for a designated term of service, and each executive's term is staggered to ensure consistent yet evolving leadership.

Operations of the STB are sustained by an extensive support staff and fall within six distinct offices of the organization: (1) the Office of the General Counsel provides legal advice to the board's top executives and defends the STB in court when its actions are legally challenged; (2) the Office of Economics is mainly responsible for collecting and reporting data, supporting STB decisions with economic and policy analysis, applying economic analysis to STB models and systems, and auditing Class I railroads; (3) the STB's Office of Environmental

Surface Transportation Board

Surface transportation in the United States is an extremely large and complex system that is responsible for the movement of vast numbers of passengers and huge quantities of freight via rail, roadways,

Analysis is charged with performing environmental review of actions put forth before the agency to ensure compliance with U.S. environmental policy law and also makes recommendations to the STB regarding environmental issues and implications; (4) the Office of the Managing Director handles administrative matters of the agency, such as human resources, facility management, and budgeting; (5) the Office of Proceedings is the legal office of the STB; it is focused on researching issues pending before the STB, preparing draft decisions for the public record, tabulating case votes, and recording official outcomes; and (6) the Office of Public Assistance, Governmental Affairs, and Compliance (OPAGAC), which functions as the agency's liaison with the public, managing outreach and serving as the STB's primary point of contact with the general public and with state and local governments, the media, and industry stakeholders.

The office works to provide information and address questions pertaining to the STB's regulations, procedures, and actions. The office oversees all aspects of rail operations that fall within the agency's jurisdiction to help ensure carrier compliance with statutory responsibilities by providing assistance to those seeking information and advice in that regard.

In addition, OPAGAC is home to the Rail Customer and Public Assistance Program, which offers an informal option for private-sector resolution of shipper-railroad disputes related to rates and other charges, railcar supply and service issues, damage claims, interchange problems, employee complaints, and community concerns.

The STB's efforts are supported by the Railroad-Shipper Transportation Advisory Council (RSTAC), the National Grain Car Council (NGCC), and the Rail Energy Transportation Advisory Committee (RETAC). The RSTAC advises the STB, the secretary of transportation, and Congress on railroad transportation policy issues such as railcar supply, rates, and competitive matters pertaining particularly to small shippers and small railroads. The council is made up primarily of private-sector senior executives from the railroad and rail shipping industries.

The NGCC assists the STB with problems concerning grain transportation by facilitating communication among railroads, shippers, railcar manufacturers, and the government. NGCC membership

includes representatives from railroads of all sizes, grain shippers and receivers, and private railcar owners and manufacturers. The RETAC was created in 2007 to provide the STB with guidance related to the rail transportation of energy resources such as coal, ethanol, and other biofuels. The committee's members include representatives of large and small railroads, coal producers, electric utilities, the biofuels industry, the private railcar industry, and rail labor.

Key Objectives

In regulating the U.S. railroad industry, the STB strives to accomplish and balance a number of goals in line with U.S. transportation policy. Foremost, the STB seeks to support a safe and efficient rail transportation system serving the United States and its territories and possessions. To the maximum extent possible, the board allows competition and demand for services to result in reasonable rates for transportation via rail. At the same time, it aims to protect rail shippers by maintaining reasonable rates where there is an absence of effective competition and where rail rates provide revenues that surpass the sum necessary to maintain and expand the rail system and attract capital. Another significant objective of the STB is to cultivate the continuation and expansion of a sound rail transportation system while preserving effective competition among rail carriers and with other carrier modes in order to meet the needs of the public and national security.

The STB attempts to ensure that rail carriers can earn adequate revenues to deliver and maintain consistent, efficient, and reliable transportation services, and that they can expand or enhance rail infrastructure, equipment, and technology. It also seeks to prohibit predatory pricing and practices, avoid unwarranted concentrations of market control, and prohibit unlawful discrimination.

The board works to ensure that the regulatory process is accessible and cost-effective for all affected parties and that regulatory decisions are fair and timely. It also aims to advance the environmental and energy-efficiency benefits of rail transportation and to promote energy conservation and environmentally responsible practices among rail carriers. Finally, the STB works to encourage fair wages and safe and appropriate working conditions in the railroad industry.

In its day-to-day activities, the STB adjudicates disputes and regulates interstate surface transportation in accordance with various laws pertaining to the different modes of surface transportation. The STB's general responsibilities include the oversight of companies that are involved in transportation in U.S. interstate commerce, as well as foreign commerce that takes place within the United States or between locations in the contiguous United States and points in Alaska, Hawai'i, or U.S. territories or possessions.

The surface transportation issues that generally fall under the STB's jurisdiction are railroad rate and service issues, rail restructuring transactions—including line mergers and divestitures, construction of new lines, and abandonment of existing lines—and associated labor matters, and certain rate issues tied to trucking company, moving van, and noncontiguous ocean shipping operations. Some structural, financial, and operational issues among intercity passenger bus companies and certain pipeline matters not regulated by the Federal Energy Regulatory Commission are also under the STB's jurisdiction. In performing its duties, the STB promotes substantive and procedural regulatory reform where appropriate.

A critical responsibility of the STB is to provide a forum for the efficient and effective resolution of disputes. It does so through the granting of regulatory exemptions where appropriate, the streamlining of decision-making processes and applicable regulations, and the consistent and fair application of legal and equitable principles. The STB's focused dispute resolution process facilitates appropriate market-based business transactions in the surface transportation industry. Through rulemaking and case disposition, the board strives to develop innovative ways to effectively analyze unique and complex problems affecting surface transportation, to come to fully justified decisions more rapidly, to reduce the expenses incurred with regulatory oversight, and to encourage private-sector negotiations and resolutions to problems whenever warranted.

Reauthorization

There have been several attempts over the years to reauthorize the Surface Transportation Board through legislation. One of the most recent efforts was bill S. 158, the Surface Transportation Board Reauthorization Act of 2011. The proposed

legislation was nearly identical to a 2009 bill that failed to pass. The 2011 version attempted to address rate and service concerns of rail shippers and to open the railroad industry to more competition, among other stipulations.

The Surface Transportation Board Reauthorization Act of 2011 was designed to provide comprehensive updates and improved economic oversight of the railroad transportation industry to help address long-standing competitive imbalances for shippers. The bill would have done so by facilitating increased rail competition, strengthening federal oversight, and improving access to regulatory exemptions for shippers.

Among other things, the bill would have authorized the STB to revoke class exemptions to rail carrier requirements as a way to protect rail shippers from abuse of market power. It also would have prohibited the STB from issuing to any individual other than a rail carrier a certificate to acquire a railroad line or extended or additional railroad lines that included interchange commitments or other mechanisms restricting the ability of the buyer to interchange traffic with another carrier unless the interchanges were reasonable and in the public interest.

In addition, the reauthorization act would have required that a Class I rail carrier establish, upon rail customer request, reasonable bottleneck and terminal switching rates for single-line movement or interline movement rail transportation over a bottleneck rail segment in which the carrier has market dominance. It also sought to authorize the STB to require that a Class I rail carrier, including any other rail carrier deemed appropriate, make its terminal facilities available for use by another carrier in cases where it has market dominance in a terminal area. The bill also aimed to change from discretionary to mandatory the authority of the STB to establish reasonable rail rate standards for terminal use.

Under the legislation, the STB would have been authorized to revise maximum rates of relief that it could provide to railroad shippers in certain cases of rail-rate reasonableness. Moreover, the act would have revised requirements for the approval or denial of the consolidation, merger, or acquisition of control of rail carriers, authorizing the STB to take into consideration significant effects of the transaction on public health, safety, and the environment, as

well as intercity rail passenger transportation and commuter rail passenger transportation.

The bill was not well received by large railroads, which felt that the bill was strongly pro-shipper and provided the potential for railroads to lose a significant amount of pricing power, thus damaging their ability to earn sufficient financial returns. Railroad executives argued that if the railroad industry lost the ability to earn its cost of capital, the result could generate a negative impact on capital investments needed to support traffic growth, which would likely reverse the industry's strides in the areas of rail safety and service reliability.

Many rail shippers, on the other hand, felt that the modifications to the STB's authority were overdue, citing long-standing barriers to competitive access for captive shippers. They welcomed improvement in the rate-challenge process and opportunities for relief from what they viewed to be monopoly pricing power held by the railroads.

The 2011 reauthorization legislation followed in the same path as its predecessors and failed to garner the necessary votes to pass into law. However, its content consistent with previous versions and its continued presence on legislative agendas may indicate the future direction of STB authorization and oversight within the rail segment of the U.S. surface transportation industry.

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See Also: Consolidated Rail Corporation; Freight Handling; Freight Terminals; Freight Transport, Intermodal and Multimodal; Railroad Industry, Economics of; Railroads, Freight; Trains; Transportation, Economics of.

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Surface Transportation Policy Project

The Surface Transportation Policy Project (STPP) is a private nonprofit organization that works to guide communities to make smarter transportation choices through consideration of how choices regarding how we get around impact the economy, environment, public health, and social equity. Working to ensure that more diverse voices and perspectives are heard when decisions are made regarding the community's transportation needs, STPP has grown to become a national force that has helped shape decisions related to spending, approval of projects, social justice priorities, and the synergy between transportation choices and the communities these projects serve. Working with other groups that advocate greater opportunities for and rights of bikers, joggers, walkers, and others, the STPP has been able to shape decisions made in a variety of settings across the United States.

Background

Founded in 1990, the STPP's formation coincided with a growing national interest in how transportation shaped and affected communities. After nearly 40 years of uninterrupted growth in the U.S. interstate highway system and commercial aviation industry, both of these modes of transportation were nearing the saturation point. As a result, conversations regarding transportation planning and policy took on a new and significant tenor.

Rather than focusing upon how to plan, implement, or fund a given mode of transportation—such as a highway, an air terminal, or a light rail system—planners examined how different forms of transportation could be coordinated to provide communities with the best combination of services possible. The STPP was formed to ensure that these discussions considered how transportation affected the economy, the environment, public health, and social justice. Because the timing was right for such a discussion, although the STPP was a new organization, it quickly became a major player in debates regarding intermodal transportation policy and planning.

STPP played a role in the U.S. Congress' passing the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991. As the first transportation legislation to follow the completion of the

interstate highway system, ISTEA (pronounced “ice tea”) initiated collaborative planning requirements that necessitated the input of municipal, local, state, and federal authorities, as well as that of the general public. ISTEA, which expired in 1997, focused upon the creation of high-priority corridors that became part of the national highway system.

Unlike its predecessors, ISTEA provided funding for automobile, rail, and other forms of transportation. For example, ISTEA provided planning support and funding for Minnesota’s Cedar Lake Trail, the first federally funded nonmotorized trail, sometimes referred to as the first “bicycle freeway.” ISTEA also funded 80 high-priority corridors that added to the national highway system, augmenting existing routes in areas of high need. ISTEA also envisioned five high-speed rail corridors, one in the Midwest, one in the southeast, one in Florida, one in California, and one in the Pacific Northwest. Although a great deal of planning and study went into these high-speed rail corridors, funding did not follow, and other than some money allocated for improving grade crossings, nothing came of these plans until \$8 billion was allocated for this in 2009 as part of the American Recovery and Reinvestment Act. Despite this, ISTEA proved widely influential and affected subsequent legislation, such as the Transportation Equity Act for the 21st Century of 1998 (MAP-21) and the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, (SAFETEA-LU) in 2005.

Based in Washington, D.C., the STPP has continued to advocate transportation changes on the national, state, and local levels. The STPP concentrates on four broad areas: enhancing the economy, improving public health, promoting social equity, and protecting the environment. As a 501(c)(3) nonprofit, STPP relies on funding from a variety of individual donors and foundations that share its goals. Local and national foundations that support STPP include the Ford Foundation, the John D. & Catherine T. MacArthur Foundation, the Robert Wood Johnson Foundation, the Rockefeller Foundation, and the Surdna Foundation.

In the two decades since its founding, STPP has established several basic principles it pursues across the United States. It consistently seeks money for bicycle, pedestrian, and transit infrastructure, believing that these forms of transportation best reduce society’s carbon footprint while



The Cedar Lake Trail, which is sometimes called the first “bicycle freeway,” in downtown Minneapolis, Minnesota, in July 2011. It was the first federally funded nonmotorized trail and was made possible by the Intermodal Surface Transportation Efficiency Act.

also providing the most positive return for each dollar spent. STPP presses for repairing and rebuilding existing roadways before new road funding is approved, based on the belief that the neglect of certain stretches of thoroughfares disproportionately affects low-income individuals and communities.

As a reliable advocate for the revitalization of the National Railroad Passenger Corporation (Amtrak) and America’s various freight carriers, STPP favors the economic necessity of maintaining and reviving the aging rail infrastructure of the United States. A stalwart advocate for reducing urban sprawl, the STPP uses a variety of tools to achieve its goals. It produces a variety of research reports, fact sheets, and other materials to assist the general public in better understanding the issues. Its professionals also monitor how well federal and local transportation systems perform, holding their leaders accountable for an acceptable level of performance. As a result of these efforts, STPP continues to play a significant role in shaping American transportation policy, planning, and implementation.

Policy Initiatives of STPP

For its primary areas of concentration, STPP works to raise awareness of and create consensus for sustainable transportation policy. To support its goals, STPP works to address popularly held misconceptions and concerns that might interfere with the pursuit of the policies it favors. To that end, STPP both funds research that helps it to build the case for government leaders and private businesses pursuing sustainable transportation policies, and creates materials that make its position clear, cogent, and compelling to interested members of the public. This course of action has proven highly successful, and the decision to focus on the economic and health benefits of sustainable transportation policy has proven a popular way to rebut opposition.

Discussions regarding the economic impact of sustainable transportation policies have historically focused upon the increased costs following such a path causes. To rebut this, STPP has instead concentrated on the economic benefits that stem from an efficient and reliable transportation system. STPP directly addresses the reality that business owners are the primary source of tax revenue for most communities. In this role, businesses also suffer the most from the inefficiencies caused by inadequate infrastructure—delivery delays, lost employee work time, and stressed and unhappy customers.

Because unpleasant commutes reduce the available workforce, STPP emphasizes how a failure to invest in sustainable and efficient transportation systems ultimately drives up business owners' costs. Time workers spend behind the wheel of their automobiles or searching for parking is often time that is lost from the workday. STPP also emphasizes that such delays cause a tremendous amount of wasted gasoline, as cars that idle on the freeway use imported resources and increase pollution. Delays in delivery times caused by clogged transportation systems dramatically reduce the economic benefits of just-in-time inventory systems that have been implemented to increase profits. As STPP focuses on the economic costs of an unreliable and inefficient transportation system, it reduces resistance to the increased expenditures necessary to implement sustainable transportation policies.

Similarly, STPP leverages the common interest in providing a secure and healthy transportation system that will benefit all members of society. Focusing on the primary and secondary risks promoted by a

car-based transportation system, STPP addresses the risks caused by increased pollution and the crowding such a system causes, as well as the unhealthy sedentary practices of the public that are encouraged by a reliance on automobile transportation.

By demonstrating a positive correlation between a reduction in the number of children's trips made on foot with an increase in the number of overweight and obese youth, STPP again draws attention to the unintended and hidden costs associated with transportation policies that ignore the needs for more healthy behaviors. When the United States spends \$600 billion annually as a result of this inactivity, investment in transportation systems that encourage more movement begin to look less expensive. Motor vehicles are also responsible for increased air pollution, which in turn leads to increased absenteeism from school and work, emergency room visits, and death. By examining the health costs associated with vehicle emissions, STPP effectively has built support for transportation systems that encourage walking and bicycles.

Addressing social equity concerns caused by sustainable transportation policies, or a lack thereof, the STPP has examined the disproportionate harm suffered by Americans from low-income backgrounds or those who are persons of color. Access to good jobs, education, and training, as well as necessary services and commercial opportunities, is reduced for these groups when inadequate money is invested in sustainable transportation systems.

Historically, the homes of ethnic minorities were disproportionately destroyed as the federal government built and expanded the interstate freeway system, often in the name of "urban renewal." Today, high-polluting transportation centers, such as diesel bus centers, are much more likely to be located in minority-majority neighborhoods and asthma rates among children of color have soared as a result.

The distance of these neighborhoods from jobs makes employment opportunities less likely and the increased costs of transportation reduce the likelihood of wealth accumulation for many of America's poor, especially those in rural and urban areas. Indeed, the poorest 20 percent of Americans spend over 40 percent of their income for the purchase, maintenance, and operation of automobiles. By demonstrating that increased spending for sustainable transportation systems would reduce costs

for welfare, food stamps, medical care, and other expenses, STPP again builds the case for increased spending on the infrastructure that would reduce dependence on the automobile.

Finally, STPP examines the link between the current transportation in the United States and the environmental degradation that is occurring globally. Exploring this popular issue, STPP shows how over 125 million Americans live in areas with unacceptable levels of air pollution, a condition that the U.S. Environmental Protection Agency (EPA) estimates leads to over 60,000 premature deaths per year. Additionally, many other health conditions—such as heart disease, asthma, and other respiratory diseases—are exacerbated by air pollution, with those from low-income communities suffering most severely.

The effects of air pollution are not limited to humans, as the EPA also estimates that smog and acid rain kill over \$3 billion worth of crops each year. Additionally, paved roads greatly increase water pollution, allowing benzene, soot, additive methyl tertiary butyl ether (MTBE), and other contaminants to enter the groundwater. High energy consumption and increased animal road kill are also directly attributable to our current transportation policies. STPP emphasizes these ills as a way of increasing support for more sustainable transportation policies and spending.

Conclusion

For over two decades, STPP has worked to build consciousness regarding the harm the automobile-centered transportation policies pursued by the United States over the past seven decades have caused, and has worked to build coalitions to support a change to more environmentally sustainable practices. By emphasizing the economic, health, social equity, and environmental problems with our current course of action, STPP has been successful in getting increased attention paid to possible alternatives. While a great deal remains to be done, the changes effected over its existence have proven to be significant, substantial, and lasting. As more political leaders from a variety of backgrounds become open to sustainable transportation policy, STPP's influence should continue to grow.

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See Also: Benefit–Cost Analysis of Transportation; Commuter Paradox; Environmental Justice; Intermodal Surface Transportation Efficiency Act; Nonmotorized Transportation; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Social Equity and Discrimination in Transportation; Sustainable Transportation; Transportation Equity Act for the Twenty-First Century; Transportation Planning.

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Surface Transportation Program

The Surface Transportation Program (STP) is a program providing federal funding for a wide range of transportation projects, and is historically the largest and most flexible federal highway program. The Surface Transportation Program is one of the four core federal surface transportation programs funded by the Moving Ahead for Progress in the 21st Century Act (MAP-21), which was signed into law in July 2012. After several years delay, MAP-21 succeeded the previous surface transportation funding bill, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), which had expired in 2009.

Under MAP-21, most federal surface transportation funding is disbursed through four consolidated programs: the Highway Safety Improvement Program, the Congestion Mitigation and Air Quality (CMAQ) program, the National Highway

Performance Program, and the Surface Transportation Program. The STP distributes funds to a wide range of transportation projects. Projects that can apply for funding may be located on any highway receiving federal aid, which includes the entire National Highway System, any bridge on any public highway, and intracity or intercity bus terminals and facilities. Further, they must be developed consistently with the required Regional Transportation Plan, conform with the Clean Air Act and relevant amendments and other environmental requirements created by law, and abide by Title 23 and/or Title 49 of the U.S. Code.

Project types as defined in Title 23, Chapter 1, Section 133 of the U.S. Code include transit capital projects that provide intercity bus service; highway and bridge projects, including the construction of new projects and the rehabilitation, restoration, resurfacing, and reconstruction of existing projects; transportation safety infrastructure projects, hazard mitigation, railway-highway grade crossing elimination; research and development programs; transportation planning programs; transportation management systems; wetlands and natural habitat mitigation; environmental restoration and pollution abatement programs; and any environmental mitigation and right-of-way construction associated with the above.

Common preventive maintenance programs also funded include seal coats, corrective pavement grinding, drainage system repair, and rehabilitation of joint and shoulders, but not spot applications, which apply for separate normal maintenance funds.

The STP originally included carpool, bicycle, and pedestrian projects, which were expanded under SAFETEA-LU and have been reduced and grouped together as Transportation Alternatives under MAP-21. MAP-21 also added \$5 billion in new responsibilities to the Surface Transportation Program, while increasing program funding by \$1.2 billion, to \$10 billion. MAP-21 folded into the STP the previously separate programs Equity Bonus, Appalachian Development Highway System, and Border Infrastructure Program. Equity Bonus had previously been known as Minimum Guarantee and was designed to return at least 92.5 percent of gas tax revenue to states, a political measure to make the federal gas tax (the rate of which has remained unchanged since 1993) more palatable.

Under MAP-21, the original Equity Bonus program is replaced by a formula to base state apportionments of highway formula funds on each state's share of 2012 apportionments. The Appalachian Development Highway System is a system of roadways and corridors throughout the 13 states of the Appalachian region. MAP-21 left funding for this program unchanged insofar as previously allocated funds remained available, but no new funding was added.

STP covers up to 80 percent of the total cost of an approved project, with state or local governments providing the remaining funds. States are also required to allot an amount equal to 15 percent of the funds they received from the 2009 Highway Bridge Program to fix bridges that are not on the federal highway system. This is in addition to the STP money states are required to distribute to metropolitan areas.

This is the first time STP has assumed responsibility for the 460,000 federal-aid bridges outside the National Highway System, which previously were eligible for funds under a Highway Bridge program eliminated by MAP-21. While MAP-21 reduced the number of bridges eligible for federal funding for repairs, it also failed to increase STP's funding to account for those bridges that retained eligibility.

In an age in which economic policies favoring strong states' rights over strong federalism have been revived by a staunchly conservative Republican Party, the existence of the STP has been called into question. In theory, the federal role could be reduced or eliminated entirely, with both the gas tax and the responsibility of maintaining highways transferred to the individual states. The best argument against this is that the federal gas tax already exists, while the political consequences of 50 separate battles to enact a new gas tax in the states could be severe enough that highways in at least some states would surely go unfunded for a time.

The major rationale for the STP is that there is a compelling national interest in maintaining the existence of a functioning and healthy intercity transportation system, which is far more critical to the nation's health today than it was a century ago, when federal highway aid was first instituted. The federal government is able, indeed is expected, to engage with concerns that may seem abstracted or too long term minded to be handled at the state level, such as environmental impact concerns, or

the long-term need to increase mass transit coverage and ridership in order to prevent unmanageable traffic and undesirable emissions levels.

Further, there are a significant number of transportation projects that straddle multiple states or other jurisdictions. If the responsibility for such projects were left to the individual states, they might be indefinitely postponed while various jurisdictions battled over the allocation of responsibility.

In New England, for example, southern New Hampshire serves as a bedroom community for Boston, Massachusetts, and also provides sales-tax-free shopping for the greater metropolitan area, so a program to extend Massachusetts Bay Transportation Authority (MBTA) service from Boston to southern New Hampshire communities has the enthusiastic support of both states but is continually stalled by disagreements over which jurisdiction should provide what level of funding support.

MAP-21 also changed the process of environmental review for STP projects by adding to the number of exempted project types. Environmental review in the form of environmental impact studies and the production of environmental impact statements, combined with the opportunity for the public to become engaged with the planning process, has been a cornerstone of the federal government since 1969.

The new process exempts projects that involve repairs or new construction in response to a natural disaster, projects on sites already home to transportation projects, and projects primarily federally funded but costing \$5 million or less. For those projects not exempt, the federal agency conducting the review is given a four-year deadline—less than half of the average length of time of a review—to complete the process or face a fine, the first time federal agencies have faced the possibility of fines for failing to complete an environmental review in a given period of time. Opponents of the new process have argued that it will lead to projects being rejected rather than risk a lengthy review that could incur a fine.

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See Also: Bridge Maintenance, Repair, and Replacement; Congestion Mitigation and Air Quality Program; Highway Finance; Interstate Highway System; Moving Ahead for Progress in the 21st Century Act; Safe,

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Sustainable Transportation

The transportation system is the backbone of economic and social progress and the means by which humans access goods and services and connect with one another. Yet, as the scale of transportation activities has grown worldwide, so too have the negative environmental, social, and economic impacts that relate to the construction and maintenance of transportation infrastructure, and the operation or use of the different transportation modes.

The concept of sustainable transportation emerged in response to these concerns as part of the broader notion of sustainable development. Given the transportation sector's significant contribution to global challenges such as climate change, it is often said that sustainable development cannot be achieved without sustainable transportation.

What Is "Sustainable Transportation?"

"Sustainable transportation" generally refers to transportation that is compatible with broader environmental, social, and economic goals. Transportation is one of many sectors that either contributes to or negatively impacts sustainable development. Therefore, it is essential to first understand the holistic principles, criteria, and policies of sustainability before considering how they can be applied to the specific context of the transportation sector.

Similarly, when focusing on sustainable transportation, it is important to recognize the broader holistic principles and issues.

The concept of sustainable development emerged over the past several decades, mainly driven by the actions of the United Nations. A particular landmark was the 1986 report *Our Common Future*, published by the World Commission on Environment and Development (WCED), also known as the Brundtland Commission, after its chairperson Gro Harlem Brundtland. This report presented what has become the most cited definition of sustainable development:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: (1) the concept of “needs,” in particular the essential needs of the world’s poor, to which overriding priority should be given; and (2) the idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future needs.

Our Common Future thus defined the major objective of development as the satisfaction of human needs and aspirations while giving equal consideration to present and future needs, and taking special note of the environmental limits for satisfying those needs. It also described sustainable development as a process of change, rather than an end goal/state. The 1992 UN Conference on Environment and Development (known as the Rio conference) was another watershed event. Since the Rio conference, it has become standard to refer to three dimensions, or pillars, of sustainability (that is, economic, environmental, and social), which all should be taken into account if development is to become sustainable.

These three dimensions are also sometimes referred to as the “triple bottom line.” The Rio conference also led to the adoption of the Rio Declaration on Environment and Development, which codified a wider set of principles of sustainable development (such as the precautionary and polluter-pays principles, as well as more process-related principles such as the need for cooperation, stakeholder participation, and integrated thinking), and Agenda 21, often referred to as a blueprint for sustainable development. Agenda

21 provides numerous directions for action and focuses on several sectors, including transportation (specifically, urban planning) and energy. The conference also adopted the United Nation’s Climate Change Convention.

However, it was not until the Rio+20 event in 2012 that the significance of transportation for sustainable development was fully recognized. In the conference’s closing document, heads of state and governments agreed that

... transportation and mobility are central to sustainable development. Sustainable transportation can enhance economic growth and improve accessibility. Sustainable transport achieves better integration of the economy while respecting the environment.

The development of transportation policies that are truly consistent with sustainable development is challenging. The introduction of biofuel blends into diesel is one such example. While this may reduce emissions of carbon dioxide, it may distort agricultural markets or cause habitat loss. It is also clear that context matters and developing countries, for example, may need substantial expansion of infrastructure to build sustainable economies, whereas some developed countries may need to transform, or even contract, their systems in response to factors such as climate change. Given these factors, some scholars have argued that crafting a meaningful definition of sustainable transportation is impossible, or even that the very notion of sustainable transportation wrongly suggests that transportation could ever become a sustainable activity in itself. Others, however, including many governments, agencies, and international institutions, find that transportation is too important for sustainability to be left without clear conceptual guidance in this regard.

This latter contention has spawned a variety of concepts, such as sustainable transportation systems, sustainable mobility, sustainable infrastructure, sustainable road management, and so forth. Such concepts become influential particularly when they form the basis for objectives and strategies adopted at local, national, or international policy levels, or for indicators to track progress toward—or away from—sustainability.

Planners and stakeholders with an even more practical view on sustainability tend to focus

directly on ways to promote certain modes of transportation perceived to be inherently sustainable, such as walking, bicycling, public transportation, car sharing, eco-driving, or the use of renewable propulsion sources. However, more cautious or subtle approaches refer to sustainable transportation more as a vision, a paradigm, or a set of principles, rather than something that could be straightforwardly defined or singled out.

Normative, Analytic, and Strategic Debates

It is useful to distinguish three interrelated strands in the sustainable development debates that have strongly influenced how sustainability has been applied to the transportation context.

The normative strand addresses the fundamental ethical principles of sustainability and development, such as those introduced by the WCED and the Rio Declaration. Different normative assumptions may be reflected in the emphasis placed on certain principles versus others. A case in point is whether the three pillars of sustainability are considered to be of equal importance, or if some sort of hierarchy is assumed, whereby either the protection of environmental systems, equitable economic development, or integrated participatory decision making is considered to be the most fundamental aspect of sustainability.

The analytic strand relies on science to determine whether an action is sustainable. In the analytic perspective, an action is unsustainable if it cannot be continued in or near perpetuity. Specific attention is therefore given to identifying system states, how they change over time, and the processes that are undermining sustainability. Natural sciences and economics in particular provide a wide range of theories and methods to help determine limits to sustainability impacts. These have helped define air quality thresholds that are applied in cities and climate change targets. Concepts such as ecosystem services, carrying capacity, critical loads, and natural capital are key examples. Analytic tools can also help define and prioritize cost-effective approaches to introducing policies to address problems.

The strategic strand relates to the system of governance—from the local to the global level—that promotes change toward sustainability through policies, programs, and initiatives. From this perspective, sustainability is more of a process where actions are continually assessed against identified sustainability

principles, policy goals, and scientific evidence to determine whether laws, policies, programs, or institutional changes are promoting the desired change.

The breadth of the issues that need to be considered (from access to local health care through electrification of the vehicle fleet to global supply-chain security) pose real challenges in drawing boundaries around the scope and responsibility of different actors in the governance mix and where transport finishes and other sectors begin. This can further complicate agreement on and the development of consistent approaches to sustainable transportation. Both the normative and analytic dimensions play important roles in the strategic dimension, but other factors such as framing and stakeholder dynamics are also essential in this context.

Weak Versus Strong Sustainability

Even if common sustainability principles can be agreed upon, there are different and even contrasting interpretations of how to operationalize sustainable development. One example is the two divergent ideas of weak versus strong sustainability. Both concepts are based on the capital model of development, according to which sustainability requires the overall stock of natural social, human, manufactured, and financial capital to be maintained.

Within this context, weak sustainability is based on the notion that natural capital (i.e., nonrenewable and renewable resources and ecosystem services) can be substituted or replaced by other capital, such as manufactured capital or technology. This implies existing resources can be consumed as long as the revenues generated from this activity are invested in a way that enables future generations to be as well off (overall) as the current one.

In contrast, strong sustainability is based on the notion that the economy must operate within the carrying capacity of the environment. The strong sustainability model rejects the idea that the most fundamental services provided by nature can be replaced by manufactured capital (for example, a water treatment plant cannot replace all of the services provided by a wetland, which also provides a habitat for wildlife, aesthetic value, and so forth).

Herman Daly developed a basic set of rules for decision making from this perspective: (1) the harvesting rates of renewable resources should not exceed the rates at which they can be regenerated, (2) nonrenewable resources should not be used

faster than renewable substitutes can be created, and (3) pollution should not exceed the renewable assimilative capacity of the environment. It is useful to observe how these contrasting views are reflected in the discourse of sustainable transportation.

Definitions and Principles

Concepts and definitions of sustainability in transportation have arisen in a variety of contexts and through different pathways. Two basic approaches to conceptualizing the idea can be distinguished: the sustainability-centered approach and the transportation-centered approach. The former springs from the international arena, where transportation is considered to be one of many sectors contributing to—or hampering—sustainable development. The focus here is on framing transportation within key normative, analytic, or strategic strands of the notion of overall sustainability. The transportation-centered approach has emerged from the community of transportation planners, engineers, policy makers, and researchers. From this perspective, transportation systems and services are the center of attention, and issues such as climate change, environmental protection, livable communities, energy efficiency, and economic development become subthemes within the concept of sustainable transportation. The majority of literature on sustainable transportation has been written from this second perspective. Both perspectives have merits and limitations in the way they balance the holistic versus specific conundrum of sustainable transportation.

The sustainability-centered perspective is important since it defines the boundaries (the ecological limits or natural carrying capacity) within which all sectors must collectively operate. It also highlights the need to establish a national framework to address sustainable development that can encourage sectors to coordinate and integrate their activities. The holistic perspective of development is where debates around the weak versus strong form of sustainability (or sustainable transportation) are best situated. In contrast, the transportation-centered view is important since it provides understanding of the dynamics of the transportation systems and connects sustainability to sector-specific transportation policies and programs, balancing social, economic, and environmental concerns.

An example based in the former perspective is the following definition of “environmentally

sustainable transport” proposed by the Organisation for Economic Co-operation and Development (OECD). Inspired by strong sustainability principles, the OECD defined sustainable transport as the following:

. . . transport that does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources below their rates of regeneration, and (b) use of nonrenewable resources below the rates of development of renewable substitutes.

In contrast, a more transportation-centered definition of sustainable mobility proposed by the World Business Council for Sustainable Development is the following:

The ability to meet the needs of society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values today or in the future.

The most widely cited definition of sustainable transportation was crafted by Canadian and European experts and adopted in 2001 as the European Union’s official policy. It seeks to combine elements from both the sustainability- and transportation-centered perspectives. It defines the following as a sustainable transport system:

1. Allows the basic access and development needs of individuals, companies, and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations
2. Is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development
3. Limits emissions and waste within the planet’s ability to absorb them, uses renewable resources at or below their rates of generation, and, uses nonrenewable resources at or below the rates of development of renewable substitutes while minimizing the impact on the use of land and the generation of noise

Table 1 Principles of sustainable transportation

Environment	Society/Equity	Economy	Governance
Adopt • A precautionary and preventative approach to decision making Avoid • Irreversible impacts • Global climate change • Pollution Encourage • Remanufacturing/reuse and recycling of transportation vehicles and equipment Ensure • The proper disposal of transportation-related toxic materials and waste Protect • Habitats/ecosystems and operate within their assimilative and regenerative capacities • Biodiversity • Environmental aesthetics	Enhance • Safety • Human health • Social well-being/quality of life Promote • Equity/distributional fairness • Access and choice • Environmental justice • Individual and community responsibility • Meaningful employment in the transportation sector	Ensure • Transportation services are affordable • Transportation is cost-effective • Natural and financial resources are used efficiently • Negative social and environmental costs are internalized—that is, the polluter-pays principle Support • Trade and business activity that enhances productiveness and contributes to development • Economic development	Encourage • Technological innovation Ensure • Transparency and accountability • Public and stakeholder participation Establish • Goals and performance objectives Support • Comprehensive and long-term planning • Interagency and international cooperation • The integration and co-optimization of policy

Source: Gudmundsson, H., R. P. Hall, G. Marsden, and J. Zietsman. *Sustainability in Transportation: Making it Count*. Berlin: Springer and Samfundslitteratur, 2013.

By its sheer length and complexity, this definition demonstrates the challenges of condensing the notion of sustainable transportation into a single statement. While it captures many aspects, it does not provide much guidance for action.

Table 1 provides a summary of basic principles that arguably provide a more flexible and operational conceptual underpinning for sustainable transportation. The fourth column that is not normally included in definitions of sustainable

transportation is the role of (national, regional, and local) governance. Several principles are shown that could be used to guide government action to support the objectives of sustainable transportation and sustainable development.

Many of the principles in Table 1 are not new and have been long understood as important by transportation professionals. However, the recognition that all of these principles could be important to decision making poses new challenges to the

breadth of the transportation planning and service delivery task.

Similarly, important drivers such as rapid technological change and increases in personal wealth can shorten the time period available to address emerging problems/externalities. For example, the rapid motorization of much of the developing world produces challenges on new scales that will require innovative and urgent action to resolve. The interest in identifying and implementing sustainable transportation solutions has perhaps never been greater.

The pathways toward these solutions are likely to be found in a broad range of instruments, such as technological innovation, investment (particularly in mass transit), regulation, taxation, user charging/fee rebates (“feebates”), direct marketing, and capitalizing on the potential for active travel. If the solutions are to be effectively integrated, there is evidence that broader strategic approaches such as multimodal or integrated planning and sustainable urban mobility plans will be important tools to bring together the actions of a range of different bodies charged with delivering transportation. Clear principles, goals, and monitoring frameworks can facilitate the ways in which different actors understand their role.

While there is no established discipline of sustainable transportation analysis, it represents a rapidly developing field of inquiry where transportation systems, behaviors, and policies are challenged from a comprehensive perspective with a particular view to environmental impacts and limits.

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See Also: Air Pollution/Air Quality; Alternative Fuels; Energy Costs; Environmental Impacts; Environmental Justice; Green Fuels; Green Transportation; Greenhouse Gases; Low-Emission Vehicles; Road Ecology; Smart Growth.

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Tax Increment Financing Districts

A tax increment financing district (TIF) is a distinct geographical area within a city or town in which an economic development policy known as tax increment financing is implemented, generally in a blighted area, as a means of funding public infrastructure improvements that will foster real property development and real development. Tax increment financing allows the municipality to freeze the taxable property value for the specified area for a limited time, and revenues from subsequent increases in property value are placed into a fund that is used to finance improvements in the district, which could include land acquisition, site development, property rehabilitation, transportation improvements and investments, water and sewer expansion, and building expansion.

First used as a funding technique in California in 1952, the rapid growth of TIFs began in the early 1980s when local governments were confronted with cuts in federal funds for economic development and infrastructure projects. By 2011, TIF laws existed in 49 states and the District of Columbia, although regulations varied greatly across states. Controversy accompanied the increase. Critics charged that TIFs were ineffective; unfair to other taxing authorities, such as school districts;

and susceptible to misuse. In 2011, the California Supreme Court upheld Governor Jerry Brown's elimination of redevelopment agencies and TIFs, but the battle over TIFs continues in California and many other states.

History and Structure

Urban redevelopment was a hot-button issue during the 1940s. From 1941 to 1948, legislatures in 25 states passed urban redevelopment acts to give local governments tools to address urban problems such as blight, degraded buildings, and a lack of affordable housing. Congress passed the Housing Act of 1949 as part of President Harry Truman's Fair Deal. Among other provisions, the act authorized \$1 billion in loans to help cities acquire slums and blighted land for public or private redevelopment. It also allotted \$100 million every year for five years for grants to cover two-thirds of the difference between the cost of slum land and its reuse value.

California passed its Community Redevelopment Act in 1945, allowing the state to create redevelopment agencies (RDAs). Eager for their share of the federal loans and grants, California voters approved a constitutional amendment in 1952 that allowed RDAs to use tax increment financing to fund their redevelopment plans, thus generating local revenues that could be used to match federal funds for urban redevelopment. TIFs did not spread quickly beyond California, with only six additional states passing

enabling legislation by 1970. Oregon made TIFs legal in 1960, and Florida granted local governments the right to set up TIFs in 1969. Most states took a more conservative approach to implementation.

For those states that did adopt appropriate legislation, tax increment financing allowed redevelopment agencies to capture increased property tax revenue in their project areas to fund their activities. Although policies and procedures differed somewhat from state to state, the basic process was the same.

The first step required a local government, under the authority of an RDA, to identify a blighted area within its boundaries where redevelopment was feasible and declare the area a TIF with a limited life span, typically 20 years, although the period could be as long as 50 years. The redevelopment initiatives are controlled by the city, either directly or via an economic development agency that is typically under municipal control. They may be funded on a cash basis or, more often, by issuance of bonds.

After determining the existing tax base of the TIF for a specified year, the agency estimates the local tax revenue growth that would occur within the TIF as a result of targeted improvements. The assessed valuation of property within the TIF is then frozen at the base year. This assessed value of the property determines the taxes that will belong to all the taxing authorities (county, school district, fire district, etc.) within the TIF.

All the assessed value above the base value—a portion referred to as the incremental assessed value—belongs to the TIF, and no other taxing authority has a legal claim on this value, unless specified by law. Capital projects that will encourage redevelopment and leverage private investment within a TIF are constructed with debt that is paid off by the increased property taxes received as a result of the improvements.

When the designated life span of the TIF expires, all the tax revenues from both the base assessed value and incremental assessed values revert to the general fund, thus increasing tax revenues that benefit other taxing authorities or reduce tax rates for taxpayers. The rationale underlying TIFs is simple: large public projects increase the value of nearby private property, thus increasing tax revenues. If a public agency funds a redevelopment or infrastructure improvement project, the money to repay the debt comes from the incremental increase in tax payments. The actual growth that individual

TIFs produce can vary considerably, even within the same state or same city. However, even modest growth can be a wise investment if the growth would not have occurred in the absence of the TIF.

For two decades, TIFs were in limited use, but that practice changed in the 1970s. Federal funds for urban renewal agencies were cut, but the need for infrastructure improvements and economic development were still pressing. In 1978, California's Proposition 13, which cut property taxes by 30 percent and capped the rate of increase for the future, became the law noticed round the country as tax revolt at state and local levels spread.

Within five years after Proposition 13 was passed, nearly half the states had adopted some measure to limit the government's ability to raise taxes. Since redevelopment agencies were separate legal entities and not governed by the new tax laws, the popularity of TIFs increased significantly in the wake of these changes. Many states also used TIFs to provide public financing, tax incentives, and regulatory relief to businesses they were courting for location or relocation within their borders. By 1984, 28 states allowed the use of TIFs. By 1987, 33 states had adopted legislation that authorized TIFs, and by 1992, the number had reached 44.

TIFs were originally justified as a means by which local communities could self-finance the redevelopment of blighted urban areas. With the proliferation of TIFs, they were used in both blighted and non-blighted areas for a range of projects associated with redevelopment, development, or related physical infrastructure improvements, such as elementary and secondary schools, roads, bridges, parking facilities, recreational facilities, water and wastewater facilities, and electrical power plants.

To prevent abuse of TIFs, about 20 states made a legal requirement for authorizing a district (the "but-for" determination), that the anticipated growth in tax revenues would not happen but for the capital projects funded by the TIF. Even in those states with no legal requirement, political pressure existed to address concerns that the payment of TIF project debt will come from a new source of revenue rather than revenues that would have been created without the district.

Benefits

The widespread and long-standing use of TIFs as an economic development tool attests to their

effectiveness and flexibility. Proponents argue that TIFs prove their effectiveness in a variety of ways. TIFs attract businesses and industries to locate or expand within the targeted area, resulting in increases in jobs, wages, and property value and taxes. TIFs have not only financed successful commercial and industrial projects but they have also built affordable housing, helped in the revitalization of low-income and moderate-income neighborhoods, and addressed environmental problems, such as redeveloping brownfields and properties that have been abandoned or underutilized because of actual or perceived contamination to the environment.

Once the blighted area is revitalized, the economic growth created may reach beyond the district. Economic and population growth associated with the TIF may generate greater revenue sources for the local government through increases in local income taxes, sales taxes, and motor vehicle excise taxes. For example, there is empirical evidence that TIF programs in Michigan accelerated property value growth, and TIF programs in Indiana raised property values and employment levels.

TIFs have also proven to be a broadly useful development tool. Communities across a wide range of socioeconomic characteristics have used them successfully to deal with problems as varied as tax and expenditure limitations, infrastructure demands from population growth, and declines in intergovernmental aid. TIFs have unified normally antagonistic groups (including developers, neighborhood groups, and local government officials) to form an effective public-private partnership that may benefit redevelopment within the larger area.

One of the most attractive qualities of TIFs is their self-financing apparatus. They are able to tackle important projects that have significant economic impact without increasing taxes or requiring other direct public investment. TIF projects are funded through the increased tax revenues that the projects themselves generate rather than requiring subsidies from other overlapping governments.

If the project requires that bonds be issued, the municipality is able to issue tax-exempt bonds with low interest rates that will be paid from the incremental lift rather than from the general funds. After the bonds have been paid, the local government and local nonmunicipal districts, such as school districts, will benefit from increased taxes from the revitalized area.

Flexibility is another primary strength of TIFs. They can be authorized in areas that meet the legal requirements of the particular state, and they can be applied to any financially feasible project, regardless of size. They can also be inaugurated at any time a development opportunity is identified. Perhaps most important, they are flexible enough to be used in combination with other financial incentives to retain and expand businesses or attract new business to the community. Local control allows TIFs to avoid the bureaucratic delays and seemingly infinite red tape too often associated with intergovernmental revenue.

Transportation Improvements

State laws determine the kinds of TIF projects that can be authorized. From the earliest TIFs, infrastructure improvements, which can include improvements to roads and highways, have been part of the package. However, as cash-strapped cities needed funding for vital transit improvements and extensions, more TIFs were employed specifically to fund transit projects.

TIFs have been used to fund wholly, or in conjunction with other programs, projects as varied as the construction of streetcar lines in Seattle, Tampa, and Portland to Atlanta's eight-lane, yellow 17th Street Bridge over the I-75/85 Downtown Connector, part of the city's extensive TIF-funded Atlantic Station Steel Mill Redevelopment Project.

Illinois allows TIF funds to be applied to infrastructure and transit projects. Chicago, a city with almost 30 percent of its area designated as TIF-defined districts, funded three transportation projects in the central city in this manner. These projects include the Randolph/Washington station, the Dearborn subway, and various transit projects within central Chicago's Loop. The city allocated \$42.4 million in TIF revenue to the Randolph/Washington station. In the capital improvements element, \$13.5 million of TIF revenue has been funded for this project. The Randolph/Washington station project was implemented through an intergovernmental agreement on infrastructure expenses, such as track and tunnel connection.

Oregon was within the first group of states to make TIFs legal. Portland's Gateway community was designated as a TIF in June 2001. The plan reflects a \$164 million budget spanning over 20 years. Projects include a new transit center, a new



Atlantic Station is a neighborhood in midtown Atlanta, Georgia, consisting of 138 acres located on the former site of the Atlantic Steel mill. The redevelopment of the land was financed not only by private investments but also by a special tax district, which helped pay for public utilities such as streets, sidewalks, and sewers. The yellow 17th Street Bridge was constructed over the I-75/85 Downtown Connector expressway and is the primary access to and through Atlantic Station. The bridge is an enormous eight lanes wide.

medical building, low- and moderate-income housing, realignment of dangerous intersections, and wider sidewalks, increased pedestrian lighting, and other infrastructure improvements.

The largest urban brownfield redevelopment in the United States, Atlanta's Atlantic Station sits on 138 acres adjacent to midtown Atlanta on land once occupied by the Atlantic Steel Company, a steel mill that was active between the 1920s and 1980s. Authorized in 2001, the TIF designated funds for environmental remediation, general site work, utilities, and transportation infrastructure. In 2006, this TIF generated over \$8 million in revenue. Bike lanes were added to the streets, and wider streets will eventually accommodate a dedicated transit line. Currently, Atlantic Station

provides its own free trolley shuttle, which runs every five minutes.

A 2012 study revealed the average vehicle miles traveled is significantly less in the area than the regional average, with residents traveling, on average, 7.8 miles per day. Twenty-five percent of total trips within the community were in non-single-occupant vehicles; the number almost doubled for residents and employees.

New York has used TIFs since the 1950s, but has never used the program as widely as other states. That may change since New York expanded its TIF law in 2012, allowing school districts to opt into the program. Even before the change in statute, the extension of the No. 7 subway line of the New York Metropolitan Transit Authority (NYMTA)

was financed by the sale of \$2 billion worth of New York City municipal bonds. Using TIFs, New York City raised \$1.4 billion slated for the subway extension; the remainder of the funds will be used for other infrastructure improvements in the Hudson Yards area.

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See Also: Economic Development; Transit Finance; Value Increment Tax.

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Taxi Drivers and Labor Issues

Taxis play an important role in urban and, to a lesser extent, rural transportation. Taxicabs are popular symbols of modern urbanity, and their drivers are at the forefront of public consciousness as an omnipresent participant in urban street culture. A mobile and divided workforce, taxicab drivers face a number of health and economic risks in the course of their daily work, while often remaining relatively powerless to affect the regulatory and employment structure of their work environment. Because taxis are non-fixed-route transportation, taxi drivers play an unusually central responsibility in the management of their own work time and the servicing of the public; thus, driver skill and the viability of taxi driving as an occupation are important, though sometimes neglected, concerns for policy makers seeking to improve the service quality of the industry.

A taxi (or taxicab or cab) is a general term applied to non-fixed-route vehicles for hire to the public, particularly in urban areas. The term is also sometimes used for semi-fixed route services, such as the bush taxis of rural Africa, or the shared taxis of South Africa. Local governments often apply the name more narrowly, in order to distinguish between several different types of such vehicle, depending, for instance, on the mode of hire (from the street or by prearrangement) and rate of fare, but, for the purposes of social science, it is simpler

to use the term *taxi* as a general designation for all such services.

The most common vehicles used as taxis are gasoline- or electric-powered automobiles, but similar services use motorcycles or bicycle rickshaws. Besides legally defined categories, there also exist varieties of informal taxis. These operate either by mimicking the signage and operation of formal taxis or as “vernacular” taxis, often unmarked, serving particular communities, such as ethnic or impoverished neighborhoods, which are underserved by the formalized taxi system. The labor issues described here apply most directly to formal automobile taxis, but similar conditions apply broadly to drivers of informal and nonautomotive forms.

Compared to other classes of transportation workers, such as public bus drivers, taxicab drivers typically have a lower income, less job security, and fewer employment benefits. This is at least in part the result of the taxi industry being the domain of private business rather than public transit, and because taxi drivers are often a disorganized and disunited workforce. Some of the causes and consequences of this are discussed below, beginning with the risks faced by drivers in the course of their work.

Occupational Hazards

Globally, and even within individual cities, the working conditions of taxicab drivers vary widely, because of differences in employment models and class context. Nevertheless, taxicab drivers everywhere face a similar list of occupational hazards, from the threat of injury or violence on the job to income uncertainty and the long-term health effects of spending hours in a vehicle in urban traffic.

Temporal variation in demand for taxis is a major problem faced by operators. Passenger demand can vary greatly according to daily, weekly, monthly, and seasonal cycles. The viability of taxi driving as an occupation depends on cross-subsidy, whereby income from busy times subsidizes slow times or when no business can be obtained. The timing of payments owed by drivers—vehicle leases, insurance, financing payments, inspection and licensing fees, and taxes—affects their vulnerability to income fluctuations.

Health risks associated with cab driving include wrist and back injuries resulting from repetitive motion, prolonged sitting, and lifting luggage; skin

cancer from exposure to sunlight; respiratory problems from breathing auto exhaust; possible physical harm from traffic accidents or assaults by passengers and/or robbers; and stress from prolonged attention to driving, dispatch, and the cab’s surroundings. The economic context of the occupation affects drivers’ exposures to these risks. Thus, the need to pay a cab lease, or to meet insurance or financing payments, may push drivers into working longer hours or taking more risks, such as speeding in traffic, or accepting potentially dangerous fares.

When numbers of drivers are high and competition for passengers is fierce (for instance, in cities with little or no restrictions on entry into the taxi business), drivers may turn to illegal means to supplement their income. Particularly in many developing world metropolises, taxi kidnappings and robberies of passengers are a sporadic threat. Nevertheless, taxicab drivers are generally more likely to suffer from violence than are passengers.

Although sometimes tolerated by police and regulators, drivers of informal taxis may also face the costs of fines or bribes to stay in operation, along with the risks of vehicle seizure or other penalties; for these reasons, informal drivers often operate at night or in marginal neighborhoods away from the sight of police, exposing them to further dangers of victimization.

Employment Context

Three interrelated factors play key roles in shaping the labor conditions faced by taxi drivers. These are (1) the relative amount of influence or control drivers have over their own working conditions, (2) the occupational prestige and class context of taxi driving as an occupation, and (3) the extent to which drivers are considered to be skilled or unskilled, and the extent to which driver skill is recognized or cultivated by regulation and the industry in general.

The amount of influence or control drivers exert over their own working conditions depends largely on the occupational structure and regulatory framework of the industry. In any given city, taxicabs may be organized into large fleets, or as a multitude of independent owner-operators, or as a mixture of both. For much of the 20th century, it was common for fleet drivers in parts of the developed world to be employees, often unionized, typically working for a commission or percentage of the income from taxi fares.

The later decades of that century, however, saw the resurgence of the 19th-century model of leasing or “horse-hiring,” with growth in the numbers of drivers renting vehicles by the day, week, or month. Lease drivers typically have fewer workplace protections than employee drivers, and, as in the United States, may be legally restricted in their ability to form unions (because they are considered to be independent contractors). This typically results in less access to health care, unemployment benefits, or workplace injury compensation. Whereas drivers working for a percentage will at least be sure of taking home some amount of income per shift, lease drivers may lose money if they do not make enough to pay for the rental of their vehicle plus gasoline and other maintenance expenses.

A third category of driver, the independent owner-operator, is common in many cities of both the developed and developing worlds. Classically, as the term implies, the owner-operator owns and operates his or her vehicle. However, more complicated possibilities exist. For example, an owner-operator may hire one or more additional drivers to keep the vehicle in operation for more hours, if this is allowed by law. Where permits are required to operate taxis, one individual may own both permit and car, and do the driving; or a driver may lease both permit and vehicle from one or separate owners, or any similar combination.

Individual owner-operators may work without any contact with other taxi drivers; in other cases, owner-operators may combine into driver associations. Driver associations provide many services: they may allow drivers to share dispatch resources (such as radio or computerized dispatch), they may petition for and maintain taxi stands for the use of the members, or they may provide vehicle and liability insurance. Driver associations also function as pressure groups for promoting the political interests of taxi drivers; for this reason, owner-operators often have a stronger political voice than lease drivers, particularly when the latter are not unionized.

Such differing employment structures may coexist in one city, leading to divisions between permit-holding, leasing, and owner-operating drivers. Such divisions among the taxi-driving workforce can be compounded by regulatory distinctions. Thus, when legal distinctions are made between modes of dispatch or hiring available to different classes of

vehicle, drivers are divided, as well, into competing and sometimes antagonistic groups.

New York City is an example of a city with such a divided taxi workforce: its taxis are divided among yellow cabs (allowed to pick up street hails downtown), black cars (which can only provide pre-arranged service), and livery cabs (which are legally limited to phone orders in certain parts of the city); the drivers of each of these are again divided among lease drivers and owner-operators. Such divisions make worker organization difficult and thus lessen the opportunities for drivers as a whole to influence the decisions of employers, regulators, or policy makers.

Social Status

The social status of taxicab driving as an occupation affects the way drivers are treated by passengers, employers, and regulators, as well as affecting drivers' own self-perceptions and their expectations about the working conditions and desirability of the job itself. Although taxi driving is a relatively low-status job in much of the developed world, this is not true everywhere. Taxicab driving is seen as a more desirable, higher-status job in conditions where it allows economic advancement or a path out of poverty, for instance, for rural-to-urban migrants.

In developing-world cities, access to an automobile in the form of a taxi may be a status symbol in itself, and taxi drivers may have higher incomes than many other sectors of the working class. Where drivers are able to purchase taxi vehicles and/or permits, upward mobility within the industry is possible, with career drivers turning into independent businesspersons over time, or even obtaining fleets of several taxis.

However, the lure of ownership may pull drivers into debt, a particular problem in migrant communities where members may be the targets of predatory lenders who specialize in loans to taxicab drivers. When permits or taxis are freely transferable, they may accrue in the hands of nondrivers, with prices outside the range affordable to working drivers. When the occupation does not offer possibilities of advancement, taxi driving comes to be seen as an occupation of last resort.

During economic downturns, it is not unusual for professionals and members of the middle class to turn to taxi driving for employment. Such drivers are less likely to consider driving desirable as a

career, and are less likely to seek improvements to their working conditions than to seek an exit from the occupation.

In much of the developed world, a large proportion of taxicab drivers are transnational migrants. In primary cities of the developing world, it is also not uncommon for many taxi drivers to be internal migrants from rural or impoverished regions of the country. In either case, linguistic and/or cultural differences may mark taxicab drivers as outsiders, sometimes exposing them to incomprehension or even outright hostility from the riding public. The self-perception of such drivers depends again, in large part, on whether they perceive the job to be a “stepping stone” to improved economic chances or a “dead-end” with little or no hope of advancement.

Skills

The above-mentioned economic and structural constraints notwithstanding, taxi drivers experience a relatively high degree of freedom in terms of mobility on the streets, and over their own choices of where and how to obtain business. In contrast to fixed-route transit, the service quality of the taxicab industry is dependent on the drivers' choices and desires to find and serve passengers, as well as on their skills in wayfinding, avoiding accidents or robbery, dealing with passengers, and anticipating demand. Such skills are the product of work experience or of training, but are not universally promoted by the organizational structure of the industry.

The classic exception is London, which requires prospective drivers of black cabs to complete an exhaustive course of study lasting up to three years. Training courses of shorter duration are increasingly common in other cities worldwide. Beyond such training, driver skill is necessarily the product of years of experience, giving regulators an incentive to cultivate career drivers. However, the economic structure of a given taxicab market, for reasons described above, may encourage high turnover of drivers rather than commitment to the job, resulting in high ratios of inexperienced, unskilled short-term drivers.

This lack of skill may be partially mitigated by the use of technology, such as GPS devices for wayfinding. The growth of computerized dispatch simplifies the assignation of drivers to fares, reducing

the need for drivers to anticipate and find demand. The recent spread of smartphone dispatching often combines both of these features, along with tools for constraining driver and passenger behavior, through control of payment and tipping, and of the exchange of information. Such technologies may partially make up for the lack of driver knowledge and skill based on experience but do not protect drivers from violence and injury as effectively as experience on the job.

Insofar as taxi service is dependent on driver skill, and so far as that skill is derived from experience, policy makers would find it desirable to promote the existence of drivers who approach the job as a career. This can be accomplished by assuring drivers of some voice in the decision-making process of the industry, as well as some protections against the exploitation of drivers by employers, lenders, or even other drivers.

One attempt at such protection is the limitation of the ownership of taxicab permits to active, licensed drivers, in order to prevent the control of the industry by nondrivers who profit from the industry but are not exposed to the occupational hazards involved. This reform does promote career driving; however, it does not necessarily protect drivers from predatory lending or from fluctuations in market value if permits can still be bought and sold among drivers.

Another protection is the formation of taxicab cooperatives, several models of which have emerged independently in different parts of the world. These are typically more formal than associations of owner-operators in that they bring large numbers of drivers and vehicles together into cooperatively managed fleets. Although some cooperatives have been regarded as successful, others have experienced degeneration, a process by which democratic management in worker-owned cooperatives degrades into less democratic forms. Once again, this is often associated with divisions in the workforce, particularly between permit-holding drivers and lease drivers. When cooperatives are formed among permit-holding drivers, they are likely to hire lease drivers who are not themselves members of the cooperative, thus resulting in an oligarchic rather than democratic workplace.

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See Also: Jitneys; Public Transit Employees and Labor Issues; Shared Taxis; Taxicab Licensing and Regulation; Taxicabs.

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Taxicab Licensing and Regulation

Taxicabs are a ubiquitous travel mode in cities throughout the world. In nearly all cases, the taxicab market is regulated by cities to manage fares, limit entry to market, ensure geographic reach, promote public safety, and maintain other service characteristics. The taxi industry is one of the oldest types of public transit and has been subject to license requirements for centuries. The long history of regulation includes various periods of strengthening and weakening regulations, and taxicabs are an area of local transportation policy where there is substantial variation in regulatory approach across cities throughout the world.

History and Legality

London and Paris were the first cities to regulate the taxi market. In the early 1600s, the cities required licenses for horse-drawn hackneys and limited the total number of vehicles available for hire. Since then, limits on the number of allowed vehicles has been a regular feature of local regulations, and while the original intent to ensure that operators met minimum standards was worthy, limits to entry are problematic and lead to rent-seeking and monopolistic behaviors.

For-hire services are regulated at local levels in most cases. Cities, counties, and other regional

governments design and enforce the regulatory environment. In the United States, states either allow cities to regulate taxicabs as part of their police powers or, in some instances, states require that cities regulate the industry. There have been numerous court challenges questioning the legality of local taxi regulations, but the ability of cities to regulate the market has nearly always been upheld. The current era of smartphone applications—discussed in more detail in a later section—represents a new line of legal inquiry that may challenge the historical regulatory structure, but early court cases from technology companies against the taxi industry and regulators have had mixed success.

Local control over taxi markets means that they are structured differently across cities. There are a few dominant types of markets, however. In a few cities, such as New York, street hails are the only way to hire a yellow cab. In many other cities, street hails are illegal and taxicabs must be dispatched (or booked). Other cities feature taxi stands, and often airports have their own different systems for hiring cabs. There are also regulations about sharing taxis and where drivers are allowed to pick up passengers.

Street Hails

Street hails occur where taxi drivers cruise around in search of fares and potential passengers raise their arms—or hail—available cars. Most cities prohibit street hails because the method increases the potential for discrimination based on geography or appearance. Street hails also require price regulation to eliminate fare negotiation at the point of hire. The largest justification for not allowing street hails is that taxi drivers will only cruise in the neighborhoods, usually in the central business district (CBD), where they will be able to find an adequate number of fares. This means that much of the area that potentially could be served will not be. More critically from a policy standpoint is that the concentration of taxi activity in a wealthy commercial area general drains taxi services from areas outside the downtown. Hailing tends to create geographic imbalance between potential riders and taxis.

Street hails also raise the opportunity for drivers to discriminate based on what a passenger looks like. In New York City, the yellow cabs, which are limited to street hails by law, are required to take any fare for which they stop. Of course, the word

stop leaves open a great deal of interpretation. Stories of racial and ethnic discrimination are common where taxicabs simply won't stop for a hail, although the number of fares not picked up is hard to measure beyond anecdotes.

Also in New York taxi drivers will often refuse a fare based on geography and time of day. For instance, taxi drivers have a shift change in the late afternoon. Shortly before this change, it is difficult to hail a taxicab to get to certain destinations because of the drivers' concern about getting back to their base in time to turn over their car. While these discriminatory behaviors are the exception and not the rule, they are the kinds of objections used when most other cities justify their use of dispatched or prebooked taxicabs.

Prebooked

In contrast to hailing taxicabs, many cities require prebooking or dispatch models for service. Dispatch services require the rider to call a central number, or in some cases the taxi driver directly, and a taxi is sent to pick them up. Prebooked services also include cars that shuttle passengers to airports, limousines, and other commonly used services.

There are multiple justifications for prebooked services. Cities that wish to prevent discrimination based on location or appearance seek to limit cab driver discretion in choosing fares. Absent dispatched services, few taxiscabs would be found outside central business districts or airports (or, in some cases, train stations). Beyond discrimination, pre-booked services prevent cruising for passengers, which is inefficient travel and wasteful for all involved outside of a few dense areas. Dispatched services are operated either as a first-call, first-served system where taxi cabs are sent as needed or as a scheduled service.

Shared Vehicles

Most taxicabs are limited to transferring an individual or one set of passengers at a time. Although a group of friends may share a ride and end up at multiple destinations, multiple pickups are typically not allowed. There is a special group of taxi licenses that does allow for shared vehicles in some cities, and shared taxis are often encouraged in the wake of major disruption to conventional transit services. New York City has shared taxi stands in a few locations where passengers can share a ride

and fare between the business district and popular residential locations. In the aftermath of Hurricane Sandy in October 2012, which knocked out parts of New York's subway system for over a week, shared taxis and jitneys were indispensable for maintaining mobility within the city.

Many cities regulate how multiple passengers are treated as far as the fare. Some cities allow for a separate charge for each additional passenger, while others require a single fare for each trip. For passengers, being able to split the fare is a way to reduce the cost of taxi rides and may induce additional taxi trip making.

Regulatory Frameworks

License requirements that limit the total number of for-hire vehicles allowed are very common in cities throughout the world. Ostensibly, regulators seek to determine the optimal number of taxicabs to serve perceived and real demand, then set the limits accordingly. Yet, in practice, it is extremely difficult to know how many taxicabs are actually required for any given demand, and by maintaining an artificial ceiling in the number of vehicles allowed, actual demand is not revealed. Rather, rider demand with regard to the constraints of the number of available taxis and the costs of the fares are revealed.

The iconic New York City yellow cabs, for instance, are limited to about 13,500 medallions. The Haas Act of 1937 initially placed a cap on the number of allowed franchises in order to mitigate the negative effects of the "taxi wars." Too many cars searching for fares reduced the earning potential of drivers and the competition for passengers actually reduced service quality and made passengers and operators worse off. Under the medallion system, each licensed yellow cab is required to have a physical shield, about the size of a grapefruit, stamped on the hood of the vehicle. Medallions in New York City grant the right to the holder to cruise for hails anywhere in the city, as well as protection from price competition (fares are set by the Taxi and Limousine Commission of New York City).

The restriction on total medallions has two perverse results. First, the value of individual medallions reflects monopoly rents rather than efficient pricing. The other effect is that unlicensed cabs have an incentive to enter the market. In New York City, livery cabs first appeared in the 1960s and now

number more than 30,000. These cabs serve areas of the city where the yellow cabs do not ply the streets for fares. Since New York's yellow cabs primarily cruise only parts of Manhattan, most of the city's boroughs are served by alternatives such as liveries operating in a regulatory gray area.

Fares

Taxi fares are regulated to ensure adequate earnings to cover wages and operating costs, as well as to protect passengers from fraudulent behavior. Taxi services are an example of credence goods, which are economic goods with asymmetric information and potential for fraud. Auto mechanics and physicians are also common examples.

Credence goods rely on the seller to be credible because the buyer has little way of knowing the true value of the good or service being provided. While everybody knows that they should receive a second opinion when a doctor provides a diagnosis, soliciting competing bids for taxi travel is usually impractical for all parties.

Regulated fares eliminate the need for negotiation. This not only serves the customers well, it also speeds up the process of hiring a cab by avoiding haggling over the amount to be paid on each trip.

Public Safety

Public safety is the key consideration for regulators. Many transportation scholars and economists argue that taxicab regulations should be limited to those that ensure public safety, but, even with safety, there is substantial disagreement as to what is required. The bare minimum regulation requires that all taxicabs and drivers have adequate insurance and licenses.

Vehicle Requirements

New York City is famous for yellow cabs, and London is equally famous for black cars. These are iconic aspects of the cities by design. Cities recognize the value of distinctive colors and shapes of valuable taxi services. New York's yellow cabs have inspired cities across the globe to adopt similar shades of yellow to mark their official taxicabs. By signaling through vehicle standardization, passengers are assured of a safe trip for the stated fare.

Taxi regulations often require that taxicabs look a particular way. Colors, as mentioned, are one set of requirements. In 2013, after a series of legal

challenges from entrenched medallion interests, New York City created a special taxicab license that will serve the areas of the city not well served by the yellow cabs. These new outer-borough taxicabs will be painted a specific shade of apple green to set them apart from conventional yellows.

Checker Cabs were the standard for New York's taxi services for decades. Much like London's black cabs, the Checkers were specially designed and built for taxi services. Over the past few decades, competition from conventional auto makers has resulted in a mix of available cars as taxis, and many cities have introduced fuel-efficiency standards or hybrid-engine standards to encourage particular types of cars.

Vancouver, Canada, was the first city to introduce hybrid taxicabs in 2001. In 2005, San Francisco used a Clean Air Taxi Grant Program as an incentive to increase the number of hybrid taxis, and now about 50 percent of the fleet are hybrids. Chicago used a similar program that encouraged the use of hybrids and compressed-natural-gas vehicles, and the city reduced the initial mileage allowable for taxicabs new to service. As many taxicabs new to Chicago were old taxicabs from elsewhere, especially New York City, the Chicago taxi industry quickly upgraded the fleet to newer, more-fuel-efficient cars.

As mentioned, vehicle age is another aspect of taxis that can be regulated. In New York City, taxicabs must be replaced after three years. (This forced obsolescence also partially explains why other cities have many yellow taxis; they may be used New York City taxis.) While in service, most cities require regular inspections of the vehicles to ensure safety.

Less common than vehicle age, color, or propulsion are strict requirements for the specific make of a taxicab. Most cities have guidelines for what cars can be used, but places such as London and New York go further in requiring a particular model of car.

In 2012, New York City announced the Taxi of Tomorrow, a vehicle made by Nissan that will be the primary vehicle allowed for use as a yellow cab in the city. The Nissan model was chosen after a competitive bidding process, which had a few entrants. The city wants the Taxi of Tomorrow to be an iconic part of the streetscape, although adoption of the vehicle is subject to resolution of legal challenges because the car is not fully accessible under the Americans with Disabilities Act.

Economics of Taxi Markets

Labor concerns are prevalent in taxicab regulation. Unregulated taxi markets are subject to intense competition that drives down costs and profits. Unfortunately for taxi drivers, their wages are the only part of the cost of doing business that is not fixed. Cars, insurance, and gas are all exogenously priced and owners have little ability to reduce these costs. Taxi drivers are owner-operators, independent contractors, or hired employees, although most fall into one of the first two categories.

Regardless of whether drivers are owners or hired employees, their incomes can get squeezed to the point where taxi driving is no longer sustainable. While this is exactly how the market economy works, the challenge for cities is the process of reaching taxicab equilibrium. Passengers who depend on taxis and cities that rely on taxis

to complement their transit systems cannot afford to go through periods of over- and undersupply of taxis. This is one reason why cities attempt to limit the number of licenses.

Limited access to medallions has caused the price of medallions to skyrocket in many cities. In New York City, medallions now trade for over \$1 million. Even in markets such as Ottawa, Ontario (Canada), medallions fetch over \$300,000, and in Milwaukee, Wisconsin, where one man owns half of the allowed licenses, licenses trade for close to \$200,000.

In a competitive market, these prices signal that scarcity is a problem and that the number of medallions needs to increase. Yet, for taxi markets, these astronomical prices for the right to run a cab represent rent-seeking and monopolistic behaviors. Economic rents are those that are earned without adding value to the overall economy. For \$1 million



Official taxi licenses and the medallion system were introduced in 1937 and remain in place today. The medallion system limits the number of cabs on the streets and has been criticized as an entry barrier to the New York City taxi market. It is therefore believed to contribute to the black market for illegal taxicab operations, also known as gypsy cabs. On the other hand, many believe the medallion system helps better regulate taxis, thereby enabling the city to raise the standards of all taxis.

medallions, there is no benefit to the public or to drivers from these prices. The medallion owners, however, get rich for being lucky enough to own a medallion as the price increased.

Who is harmed by rent-seeking in taxi markets? Because fares are usually regulated, people fail to see that consumers lose out. The regulated fares are higher than they would otherwise be, but there are fewer taxicabs on the road than would otherwise be expected. Rent-seeking behavior by monopolists or oligopolists also reduces productivity gains and service innovations. In many cities where the number of available licenses fails to rise and fall with demand, informal taxi services pop up, as is the case with 30,000 liveries in New York. Ultimately, rent-seeking behaviors limit the potential of taxi services and increase the cost of the service to customers, while the lucky owners reap profits earned through regulatory capture rather than business acumen.

Technological Innovation and Regulation

Smartphones have become ubiquitous and feature many applications that assist travelers with information, directions, and schedules for transit services. Taxicabs are no exception.

Technology companies challenge conventional markets through innovative ways to hire taxis or nontaxi drivers. These companies, such as Uber, Lyft, Sidecar, and others, operate as either a digital dispatch service (also known as “e-hailing”) or as a facilitator of car sharing. A company like Uber does not directly own or operate the vehicles but, rather, allows riders to book a car and pay for it through a smartphone application. These companies argue that because they are not providing the taxi service, they are not subject to conventional licensing requirements. These arguments are currently working their way through the court system, but New York City, Washington, D.C., and San Francisco have already revised their rules about e-hails.

Unlike e-hail companies, applications like Sidecar connect riders with people who are willing to pick up passengers in their own cars. This approach is a high-tech version of “slugging.” Slug lanes usually form at tolled bottlenecks, such as bridges, and the way they work is that drivers will stop and pick up people waiting for a ride, who in turn share or pay the cost of the toll. Through this mechanism, drivers make better use of their excess capacity and lower their cost of travel.

Smartphone apps that match riders with drivers work by drivers signing in as available, and potential passengers indicating through their phone that they want a ride. If the drivers accept the call, they make the pickup and drop-off. Through these apps, people are able to pick up passengers for a few hours per week and cover much of the expense of owning their car. It is not surprising that the most interest in these services is in cities where the cost of auto ownership is extremely high.

Rideshare applications are not subject to conventional regulations, at this early stage. Both e-hail and rideshare promoters often call them “disruptive” technologies, and the applications may eventually force new regulatory structures. In North America, it is usually illegal for anyone except fully licensed taxis or limousines to require passengers to pay for a ride. However, it is not illegal for passengers to volunteer payment to help cover the cost of travel. To comply with the letter of the law, rideshare companies consider payment to the drivers a gratuity and not technically required.

Conclusion

Taxicabs and other for-hire car services are heavily regulated and have been for decades, if not centuries. Early justifications for regulation limiting the number of taxicabs available addressed real concerns about service quality and the viability of the overall market. With unlimited entries, there may not be enough potential riders to maintain socially optimal levels of service. Yet, limits on entry likely have the effect of undersupplying licenses relative to socially optimal levels.

Regulators must deal with economic concerns of rent-seeking and asymmetric information, as well as complicated issues surrounding labor. As private operators, taxi drivers typically earn less than unionized transit workers and have limited ability to raise fares. Yet, in many markets, taxicabs are a useful stepping-stone for immigrants and low-skilled workers. Regulators must balance the needs of the drivers and operators with the broader public.

Established taxicab interests must now deal with disruptive technologies and smartphone applications that threaten established interests and ways of doing business. While these new entries to market and service innovations challenge the operational status quo, they may possibly increase overall taxi ridership and services. The current technological

changes happening within the taxi industry are the most significant since the advent of the meter.

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See Also: Car Sharing; Jitneys; Shared Taxis; Taxi Drivers and Labor Issues; Taxicabs.

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Taxicabs

Taxi services are part of public transit systems and should be considered in the context of passenger benefits and public costs. An examination of peer-reviewed journals in transportation, urban planning, and economics uncovers few studies that explore the personal benefits of taxi travel over the past few decades.

In the 1970s, a relatively large number of scholars were concerned with taxi service as a vital piece of the urban transportation system, but in the decades since, there have been fewer studies of taxi service. One exception has been economists looking at taxicab regulations, especially in the context of airport service. Most published articles are favorable toward liberalizing taxi policies, though there has been concern in the literature that poorly conceived deregulation may be ultimately harmful.

Taxi Services

Planning and policies for taxicabs are wide ranging. Though taxicabs are a minor mode by usage, taxi

services play an important complementary role to transit and other alternatives to auto ownership. The passenger simply wants to get between two known points, for instance, work and home after a late night in the office.

But the taxi drivers have different incentives and travel patterns as they spend many trips—but not necessarily miles—waiting or driving to pick up another passenger. Understanding these two travel markets for each taxi vehicle is challenging. A few studies modeled after demand for taxi service from passengers and others are more conceptual about the potential benefits of taxi services. Recently, many scholars have started to use Global Positioning System (GPS) data from taxis to model traffic flows and other aspects of the transport systems. Overall, however, taxicabs are a relatively unexplored aspect of urban transit, especially with regard to the accessibility benefits and the relationship to public transit.

With the advent of GPS in taxicabs around the world, there has been substantial new interest in taxis and traffic. Many GPS studies explicitly examine taxi driver behavior using the spatial data. This type of study is representative of current work, but by focusing on taxi driver behavior rather than rider characteristics and benefits, these studies leave a gap in the literature.

Even with the new interest in taxicabs resulting from GPS data, the role of taxis for personal travel is rarely explicitly studied. The travel behavior of taxi drivers tells only part of the travel story. Many open questions about driver behaviors are important for environmental and congestion mitigation.

Unlike conventional transit, taxicabs are not directly subsidized. Because there are no large public outlays to create and support taxi service, there is less reason for publicly funded research to model the cost-effectiveness of any investment. This reasoning helps explain why taxi regulations are studied, as regulations have an impact on public budgets and governance. Second, taxi service is viewed too often as a luxury good for the wealthy. However, data from the U.S. National Household Transportation Survey (NHTS) and the National Personal Transportation Survey (NPTS) show that the lowest-income households—the ones who are most dependent on transit—also take far more taxi trips than other income groups. Low-income travelers actually rely on taxis a much larger share of

their trips than the general population. One study from 1970 reported that households with incomes below \$5,000 (about \$30,000 in 2013) took about 30 percent of all taxi trips. These mode shares are consistent over time and are confirmed through recent NHTS data. The percentage of total trips made by taxi was between five and 10 times higher for households with zero or one car than for those with two or more.

An enduring challenge for the study of taxis is that as a complementary mode to transit, taxi usage is negatively affected by low levels of transit ridership. In most cases, travelers do not use taxis regularly unless they are going to the airport, but people in most cities do not take transit daily either. Taxis deserve greater attention because of the positive aspects of the service. Taxis have been found to have positive net benefits because of very low direct public spending.

The number of taxicabs allowed in any city is generally tightly regulated. Regulations that limit the allowable number of licensed taxicabs operating in a city help protect the viability of operations for drivers and license owners. Taxi licenses were originally capped in part to alleviate pressure on the existing road networks (or, as in New York City, to address market failure following the Great Depression), though there have been North American cities that have deregulated their taxi markets over the past few decades to mixed success.

In cities where the number of taxis increased after deregulation—a trend that has occurred in Seattle, San Diego, Phoenix, and other western U.S. cities—the increases were limited to hotel and airport markets. There has been little expansion of local taxi services, and the lack of expansion is potentially a lost opportunity to enhance transit ridership and decrease auto ownership by providing high-quality, door-to-door service. Certainly, an unregulated market for taxi licenses will have effects on taxi supply and quality, but these effects are ambiguous. What is known is that the numbers of taxi licenses have not expanded systematically with population growth or city size.

Researchers have reached broad agreement that there is a positive and meaningful association between the number of empty taxicabs and patronage. As the number of empty cabs increases, ridership increases. While this relationship is documented, the causal mechanisms are less understood.

There has not been a clear trend toward stronger or weaker regulations of taxi markets in cities worldwide, so the effect of increased taxicab supply on patronage is not well established.

Taxicabs are an important complementary transit mode that is relatively understudied in the literature. As a locally regulated transportation system that requires very little public outlay to develop, taxicabs represent an important opportunity to improve transportation choices for all people. As researchers work with the wealth of new digital data from taxis, patterns of usage and demand are being revealed that can help policy makers engage with taxicab planning and policy from a strong base of knowledge and a better understanding of the critical role taxicabs play in urban transportation.

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See Also: Jitneys; Shared Taxis; Taxi Drivers and Labor Issues; Taxicab Licensing and Regulation; Transit Fares; Transit Fares, Elasticity of Demand of.

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Telecommuting and Telecommunications

Telecommuting impact on travel demand and the urban environment has been an important issue in transportation research for more than a decade. Transportation researchers and planners have been identifying telecommuting as one of the most important travel demand management (TDM) strategies for reducing road congestion and vehicle emissions, and thus saving energy and

improving air quality. This alternative solution will work well with other such strategies, such as car, van and bus pools, public transit, compressed work weeks, and flextime.

Telecommuting is continuing to very rapidly develop as a normal way of working in the United States and elsewhere. In the United States, the National Air Quality and Telecommuting Act established pilot telecommuting programs in five major U.S. metropolitan areas with the purpose of studying the feasibility of addressing air quality concerns through teleworking. Several U.S. states have established telecommuting programs for state employees and actively promote telecommuting in the private sector. Statistics from the European Union (EU) reflect that the proportion of employees involved in telecommuting in the 27 EU countries increased from about 5 percent in 2000 to 7 percent in 2005.

Defining Telecommuting

There is no common definition of telecommuting (or teleworking, as termed in Europe). The term *telecommuting* was coined in 1976 and defined as “the partial or total substitution of telecommunications, with or without the assistance of computers, for the daily work trip.” Most researchers have tried to establish their own definitions of the concepts. Some of the common definitions, on a more general level, are as follows:

- The combination of flexiplace, flextime, and electronic communication
- Working at home or at an alternate location and communicating with the usual place of work using electronic or other means, instead of physically traveling to a more distant work site
- Remote supervision in combination with reduced commuting
- Teleworking defined as working at home or a location closer to home than the regular workplace, using information and communication technology (ICT) to support productivity and communication

Telecommuting was originally conceived as a full-time and home-based option, and presumed to be suitable only for information-related workers. It is now recognized that telecommuting does not need to be full-time, and that jobs need not be

necessarily information-related to be telecommutable, though such jobs will remain primary targets for telecommuting.

Another form of telecommuting requires the worker to travel to a telecommuting center site, other than home, from which the employee works instead of traveling to a more distant central work location. This includes running a home-based business as one’s only job, moonlighting from home (for example, running a secondary home-based business in addition to holding another job), and/or working at nearby satellite work centers (local and neighborhood centers). An example of satellite centers could be those that Pacific Bell has established in Los Angeles and San Francisco.

Impacts of Telecommuting

Potential beneficial transportation impacts of telecommuting include reduction in highway traffic congestion, reduced emission of pollutants, and savings in energy and petroleum consumption. The actual amount and impact of telecommuting in any particular region, however, will depend on particular travel demand measures in place and other aspects such as local conditions and local transportation and land use environment.

A substantial number of efforts have been made to conceptualize the interactions between transportation systems and telecommunications applications. Researchers Patricia Mokhtarian and Ilan Salomon used the following four definitions to describe possible relationships between telecommunications and travel:

- Substitution assumes that some demand for travel will be replaced by telecommunications
- Modification, in contrast with the first, anticipates the introduction of telecommunications technology to increase the use of transportation systems; for example, trip characteristics are modified by using telecommunication technologies, by a shift in commute timing, location, linking, and trip chaining without affecting the total amount of travel
- Complementarity, which refers to the situation where both transportation and telecommunications systems will enhance the efficiency of each other

- Neutrality, where telecommunication has no foreseeable effect on trip making

Mokhtarian and Salomon classified impacts into three period classifications: short-term direct, short-term indirect, and long-term. They considered short-term direct impacts as the possible substitution or stimulation of travel due to telecommunications. Short-term indirect impacts would arise if time savings from the replacement of travel by telecommunications were used to generate other trips. Long-term impacts are associated with the changes of land use patterns facilitated by telecommunications. Theoretical studies examining the impacts on residential location and urban development indicate that telework may also contribute to increased urban decentralization and even generate more transport, but, so far, there is little empirical evidence of this.

On the effects of home-based telecommunication in order to substitute telecommunication for commute trips, some researchers observed a significant reduction in work-related travel and a contraction of activity space for telecommuters as a result of telecommuting. Those reductions are due to eliminating commute trips. They also found that telecommuters not only substantially reduced their trip making and the total distance traveled but also chose nonwork destinations that are close to home.

Similar findings by other authors displayed that the share of activities performed close to home increased considerably for telecommuters on telecommuting days, and there was a contraction in the size of the activity space for telecommuters on commuting days. Findings of some studies supported an idea that telecommuters live farther from their jobs than non-telecommuters, but the substitution effect of telecommuting prevails because the longer commute distance of telecommuters is offset by the lower frequency and high speed of these trips.

In terms of the quantity telecommuting impact on travel, studies generally found that this effect is rather small. Researchers argued that although telecommuters travel less than non-telecommuters, the overall effect of telecommuting is less than might be expected.

In assessing the potential impact on vehicle miles traveled (VMT) or total person miles traveled, one researcher found a 27 percent reduction in personal vehicle trips and a 77 percent reduction in vehicle

miles traveled (VMT) on telecommuting days compared with days before they telecommuted. This finding is consistent with findings of other studies.

Dennis Henderson and Mokhtarian found that telecommuters have 32 percent fewer trips and 67 percent fewer VMTs on telecommuting days than on non-telecommuting workdays. Salomon, Mokhtarian, and Susan Handy consistently found that the overall effects of telecommuting are no more than 1 percent of total household VMT.

Mokhtarian suggested that "overall substitution effect of telecommuting will remain relatively flat into the future, even if the amount of telecommuting increases considerably." More recently, Sangho Choo and others conducted a multivariate time series analysis to estimate the impact of telecommuting on total VMT for personal transportation, using aggregate nationwide data. Their conclusion is that telecommuting reduces annual VMT, but by a very small amount—less than 1 percent.

Henderson and Mokhtarian also found no significant differences between noncommuting travel on telecommuting and non-telecommuting days. This result is echoed by others.

Despite the extensive research on travel effects of telecommuting, studies do not have a good estimate of the amount of travel that will be substituted or generated when saved commute time is available to a telecommuter. Handy and Mokhtarian discussed the various ways that telecommuting is measured and difficulties involved in comparing estimates from different surveys. In other research, the data reported telecommuters differ across studies depending on whether a survey includes self-employed people, independent contractors, part-time workers, or workers with more than one job.

Determinants of Telecommuting

The advances in information and communication technologies over the past decade may have changed some of today's employees' preferences and attributes. However, the adoption of telecommuting, in general, is still taking place more slowly than its strongest proponents expected, perhaps because of the diversity of various attributes and constraints. The reasons and motives for telecommuting are related to organizational characteristics, type of job, relations between employees and management, relations among fellow employees, and characteristics of the household and the individual.

Commute distance is considered to be one of the primary factors that influence workers' propensity to telecommute. In most telecommuting studies, telecommuters had longer commute distances than other workers. Studies also reported that employees who have stressful commuting trips, including traffic congestion, are likely to telecommute more frequently than others.

A financial incentive also influences the decision to telecommute. If the worker is given a salary increase for telecommuting, he or she is more likely to telecommute, while if there is a financial cost for working from home, workers are less likely to telecommute. Time squeeze for employed parents, especially the mother, has been put forward as one reason for a person teleworking, as well. Several studies indicate that women opt for flexible work arrangements for better child care arrangements, whereas men use these arrangements for other job-related reasons. Mokhtarian and her colleagues found that women were more likely to mention family benefits as a motivation for teleworking than men were. Mokhtarian and Salomon also found that greater income and education facilitated telecommuting, whereas age tended to act as a constraint.

Overall, it can be concluded from considerable literature in this area that telecommuting is linked with diffusion of new information and communication applications and services, and is influenced by both work-related and sociodemographic factors of telecommuters.

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See Also: Commuting; Employment Location; E-Shopping; Neotraditional Neighborhoods and Transportation Impacts.

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Telematics

When used in reference to the automotive industry, the term *telematics* refers to the integration of telecommunication and information systems into vehicles, resulting in an improved driver or passenger experience and additional safety features. The benefits can be summed up as added "vehicle intelligence." The essence of telematics in vehicles is this intelligence, combined with increased options for connectivity and communication with other sources of information, media, and, potentially in the future, other vehicles.

Technological Convergence

There is a greater trend in the field of technology and innovation—that of "convergence." With increasing sophistication of microelectronics, the boundaries between distinct and separate electrical devices are being blurred. In the past, you would have a telephone for phone calls, a record or CD

player for music, a “wireless” for radio reception, and a television for moving pictures.

With digital electronics and file formats, there has been the emergence of devices that fulfill multiple needs. Mobile phones are able to play multiple types of media and act as entertainment devices; laptop computers are able to make phone calls using Voice Over IP (VoIP); and smart televisions are able to browse the Web. Computers, once used as machines of work, now fulfill entertainment functions.

Within information technology (IT), the types of devices used for work and communication are changing with the rise of mobile computing and the tablet. Within the vehicle, there is now the provision of entertainment, but also devices that allow work and communication while drivers and passengers are on the move.

With increasing complexity, these systems can now integrate with vehicle sensors and systems to provide communication between the vehicle and the wider world to provide enhancements to the driving experience.

Further, it is likely that the sophistication of in-car telematics is only going to increase and the degree to which vehicles can integrate with existing media and communication devices will follow a similar pattern. It is this increasing integration and the blurring of boundaries between devices that is the hallmark of technological convergence—and it is at this intersection of technologies that the potential for exciting developments in vehicle telematics is seen.

The Electrification of the Motor Vehicle

The ever-increasing integration of telematics technology into motor vehicles can be seen as part of a continuation of the trend toward increasing “electrification” of the vehicle. Since the very early days of the motor vehicle, the steady incursion of electrical technologies replacing mechanical devices has added ever greater degrees of sophistication and precision.

Early mechanical wipers were motorized; mechanical distributors have been replaced with electric ignition systems, and carburetors with electronic fuel injection. Even mechanical hydraulic power steering is being subsumed in favor of electrical alternatives in some vehicles. The development of hybrid vehicles—as a transition technology to future ultra-low-emission vehicles continues this trend.

Next-generation vehicle technologies based on electric power trains with battery and fuel cell energy storage will potentially eliminate many of the mechanical systems of the traditional motor vehicle in favor of electrical equivalents. With this trend toward increasing electrification, modern vehicles have a multitude of sensors collecting data about the vehicle condition, performing diagnostic functions, and sensing the vehicle’s environment.

Further, as ever more functions are actuated electrically, by motors and solenoids, modern telematics systems have the ability to acquire data from the vehicle and act upon it. Telematics integrates these vehicle systems with communication technologies that allow the vehicle to communicate with the outside world to collect and broadcast additional data. Through this interaction with other sources of data and devices, there is the potential to add significant value to many aspects of the driving experience.

In-Car Entertainment

In-car entertainment has grown in its complexity. From humble origins—radios, cassette and eight-track players—modern telematics offers a dazzling array of media options. In many countries, analogue FM/AM radio is being phased out to free up radio spectrum for new digital services.

These technologies (DAB, DRM in Europe, ISDB-T in Japan, and HD-Radio in the United States) and alternative satellite radio services all offer the possibility of conveying additional information not possible with analog radio. As mobile data become cheaper and more ubiquitous, with improving communications technology, streaming radio from the Web may also be an option in the future.

Modern telematics can use additional information that can be communicated with digital radio to improve the entertainment experience. In addition, the most sophisticated in-car players will not only accept modern disc formats such as Blu-ray, DVD, and CD for audio, visual, and navigation content, but also an increasing range of digital media options such as USB, SD-Card, and other proprietary alternatives. Many manufacturers offer the option to interface with digital media devices, as well. In its most basic implementation, this is just a “dumb” auxiliary audio input, but more sophisticated implementations access and control devices are using dedicated interfaces that connect either physically or wirelessly.



Telematics systems can provide useful, if not sometimes critical, information to the driver of a vehicle. These systems typically use the Global Positioning System (GPS) to locate the driver of the vehicle on a road in the system's map database.

In many countries, there is legislation that the driver cannot be distracted while driving by in-vehicle entertainment features. In some markets, this means that entertainment applications of telematics are constrained to rear-seat passengers. High-end telematics integrates screens into the rear of the front seat headrests; headphone sockets provide bespoke audio to those using the devices. Video entertainment can be delivered by disc or solid-state device. Increasingly, with vehicle connectivity, there is the ability to access the Internet and stream media.

In-Car Communication

Early attempts to offer in-vehicle communication were radio-based and cumbersome. With the ubiquity of mobile phones, dedicated in-car phones are becoming increasingly rare. Primitive integration of car phones focused on a “cradle” to make physical connection with the phone, but now with improvements in short-distance wireless communication, the in-car telematics communicates with the occupants' phones wirelessly.

Smartphones can often be accessed via Bluetooth wireless technology, and telematics systems allow calls to be made hands-free, with telematics

also providing enhanced features such as voice dialing and steering-wheel phone controls to make communication on the move safer, which is increasingly essential because the use of handheld mobile phones by drivers is being banned by many countries and U.S. states.

What makes telematics systems unique is that in addition to offering hands-free functionality, the communication experience can be integrated with vehicle entertainment systems. Communication devices may also be used to exchange data and information with these systems.

Smart functionality can be added, too. For example, after sensing a vehicle crash or accident, the vehicle can summon assistance. Diagnostic information from the vehicle can be readily exchanged with service agents to diagnose vehicle faults remotely. Systems such as OnStar integrate the in-vehicle systems with paid-subscription call centers, which provide premium services to the vehicle owner. This powerful integration of vehicle telematics with added service features provides added value to vehicle owners.

Driver Information Systems

Telematics systems can also be used to communicate additional or enhanced information to the driver of the vehicle through advanced sensing or communications technologies.

One area where telematics can provide useful additional functionality is in the provision of traffic information to drivers. Traffic information is collated by a range of sources and can be used in a passive way—providing the driver with basic information on congested routes—but there is the potential for it to be used in an active way, that is, interpreted by navigation systems dynamically to optimize the shortest route. Information can be gathered from a multitude of different sources and services.

Navigation and Tracking

One area where telematics systems have become almost ubiquitous is in the field of navigation systems and vehicle tracking. Navigation systems have long been available as aftermarket options. As the technology becomes cheaper, it is increasingly common to see them manufacturer-fitted. Integrating navigation systems with the vehicle creates many smart opportunities for the vehicle systems to interact intelligently with the navigation system.

In some modern integrated navigation systems, the system is able to communicate with vehicle systems, providing features such as signaling preemptively as the driver approaches a turn. By combining topographical data with navigation-route data, vehicle systems are able to make intelligent decisions, such as selecting a lower gear when going up a hill if the car has automatic transmission. Where a Global Positioning System (GPS) signal is unavailable, integrated telematics systems are able to use “dead reckoning” based on feedback from vehicle sensors to gauge the vehicle’s position.

Through supplementing on-board navigation data with external communications, future telematics systems will be able to update maps with dynamic information about new roads or map changes. Navigation systems traditionally provide points of interest functionality. Future telematics systems will provide the potential to source even richer information about points of interest from the Internet.

Reading the Road

In addition to receiving information externally about a vehicle’s environment, increasingly sophisticated software, combined with the falling price of advanced sensors, is allowing vehicle telematics to sense the environment directly. Using a courtesy mirror camera, it is possible for a vehicle telematics system to “see” the same view as the driver. Using machine vision technologies, telematics systems are increasingly able to interpret features of the road ahead.

They can be programmed to recognize road signage and use this information to reinforce driver awareness. For example, by recognizing the signed speed limit in the zone the car is driving through, the telematics system is able to provide feedback to drivers if they exceed the speed limit. This could also be augmented by information from safety cameras stored in the navigation system.

Further, these machine vision technologies, augmented with additional sensors, are able to “read” the road surface and look at the position of the vehicle in relation to the white lines. Small corrections can be made automatically or, if a large margin of error starts to occur, feedback can be provided to the driver.

Telematics systems can also contribute to improving vehicle safety. Sensing hazards ahead, a vehicle

telematics system could retransmit this information to nearby vehicles that are enabled to receive the information, while flashing hazard lights would warn drivers approaching from behind. One example of a telematics system that can improve vehicle safety through reading the road is “night vision.” A camera placed behind the grille of the vehicle records images at night and highlights potential hazards to the driver using a heads-up display projected onto the windshield.

In addition to monitoring what is going on outside the vehicle, there is also interest in monitoring what is going on inside the vehicle. Such systems can be used to monitor driver fatigue and ensure that the driver is alert and focused on the road ahead. Should a driver’s concentration start to dip or should signs of tiredness be detected, stimulus can be provided. This could be audible, a vibration in the seat, or an interface with the vehicle comfort systems that would be set to provide a bracing cool breeze to make the driver more alert.

Applications of Telematics

The development of technologies to track vehicles’ locations, combined with smart payment technologies and applications for smartphones, has allowed the development of smart and flexible car-sharing services and clubs that offer vehicles on a “pay as you drive” basis. The inclusion of this sophisticated technology has added additional flexibility (or, as some see it, competition) to the car-rental business model, making it more convenient to users and reducing the barriers to making a car rental transaction. The smart technology has reduced the need for users to pick up vehicles from large centralized hubs, while the smart payment technologies reduce much of the administrative overhead of car rental.

The vehicle telematics system communicates GPS information about the vehicle’s whereabouts over the Internet. Users can then use an app on their smartphone to identify a nearby vehicle that is available for rental. Using a smart card or an online validation service, the vehicle is unlocked, giving the user access. The vehicle then can be driven, and its whereabouts tracked by GPS.

Users could be asked to fill the tank when it is one-quarter full using a fuel card provided. Users are billed for their car rental either by time or by mileage. Car clubs are seen as a vital tool to reduce

vehicle ownership and to promote sustainable technologies. Telematics technologies are enabling new business models that make this possible.

Fleet Management

Some companies are heavily reliant on transportation as part of their business model. This entails managing a large number of different vehicles. The physical location of vehicles is important, as the vehicles are company assets. Furthermore, the cost of running the vehicles is in proportion to the amount of miles they travel. Using telematics to track vehicles protects assets and prevents the abuse of them for non-company-related business. Through providing statistical data on vehicle performance, telematics can help fleet managers identify and diagnose problems early.

Insurance Risk Management/Reduction

Assessing and managing risk is what insurance companies specialize in. However, given the limited amount of data that insurance companies have on a high-risk group such as new drivers, it is challenging for them to make effective decisions about how to charge such drivers for insurance services. High-risk groups, such as young drivers, often get saddled universally with high premiums, which take into account statistical averages and ignore individual behavior.

Telematics technologies enable the collecting of actual in-car data about driving behavior and allow companies to reward good driving with lower premiums. Drivers can choose to have a box fitted into their car that will contain a GPS system, data logger, possibly an accelerometer sensor, and some means of communicating with a base station.

This “black box” logs driving behavior and notes anything perceived as poor driver behavior, including excess sudden braking, high speeds around corners, breaking speed limits, and unnecessarily rapid acceleration. The device automatically reports this data back to insurers to allow premiums to be adjusted. There may also be agreed rules between the insurer and their clients on specific behaviors that are being enforced, such as nighttime curfews for beginning drivers. Through having these telematics technologies fitted to a vehicle, there is an incentive on the part of the drivers to ensure that their driving behavior is impeccable. Insurance company statistics seem to demonstrate that cars

fitted with such devices have fewer accidents than those without in-vehicle telematics.

For the future, there is also the potential to integrate driver feedback into such systems. For example, rather than just passively monitoring driver behavior, such systems could make more active interventions, giving hints or feedback via a driver information display.

The Future of Telematics

While present telematics systems focus on augmenting the information that is available to the driver and providing assistance and prompts, the ultimate goal of telematics would seem to be the creation of an “entirely safe” vehicle. Volvo is one manufacturer that has set a goal of making a vehicle that “cannot crash” within a decade. This will doubtless include a significant element of telematics technology.

Looking further down the line, vehicles that drive themselves are another evolution for telematics technology. General Motors (GM) has demonstrated a prototype concept vehicle—ENV, designed for urban environments—that would be able to drive itself through the use of advanced telematics. The vehicle could also communicate with other vehicles traveling in convoy, making a larger “virtual” vehicle out of several smaller units.

Telematics systems could enable radically different configurations of vehicle, as shown in the GM ENV concept. By linking smaller vehicles virtually into what would effectively be a larger vehicle, the convoy of self-driving vehicles would provide greater utility than cars driving individually, but with the commensurate energy savings of only needing to use the exact amount of energy to move the number of people being transported on a given trip.

Communication systems would allow occupants in adjacent vehicles to talk to each other as if they were in the same vehicle. Automatic vehicles that drive themselves could answer many of the challenges of increasing urban densities, allowing vehicles to travel with shorter stopping distances as the human element of error is removed. That said, this loss of human control raises many interesting social, ethical, and policy issues.

Social and Policy Issues

Telematics technology undoubtedly has the potential to contribute greatly to social and environmental transportation goals. The improvement in

in-car entertainment is undoubtedly attractive to consumers, navigation systems offer better logistics and more efficient route planning, and safety systems have the potential to reduce some of the social impacts associated with vehicle accidents.

This added functionality and information must be balanced against the potential for distracting the driver from the most important task—driving the vehicle and ensuring the occupants remain safe. In many locales, there is legislation in place to ensure that, for example, video media systems are disabled while on the move. To what degree will motor vehicles as a product change in the future? Advanced concepts show how telematics systems could enable radically different conceptions of auto mobility, changes that will become increasingly essential given the growing population and resource constraints. These must, however, be balanced with ethical debates. As drivers hand over increasing amounts of responsibility to automated systems, the overarching question “Who is in control of the vehicle?” is a salient one.

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See Also: Automated Vehicle Location Systems; Automated Vehicle Monitoring Systems; Automobile Accident Avoidance Systems; Automobile Design; GPS, Automobile; In-Vehicle Computers.

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Terrorism, Transportation Systems as Targets of

Because transportation systems are vital to a nation’s economic wealth, as well as movement of mass numbers of people, they offer attractive targets to any terrorists willing to further their own ideology or political will. Preventative measures have been formulated over the past decades, but the total elimination of terrorist activity from any transportation system may never be possible.

Transportation systems have always been seen as “primary” targets since the early days of warfare. By cutting army supply lines by means of bombing or acts of sabotage, the net result is an army deprived of both equipment and food, becoming demoralized. Because of this, defeat becomes inevitable.

Recent wars are full of examples of invading forces targeting communications and transportation systems as primary targets before inflicting casualties on the defending forces. The 1970s saw the advent of terrorism—an unlawful use of force by organized groups for ideological or political reasons—and the transfer of these tactics from the battlefield to the cities of civilian populations.

Most major cities have public transport systems that are frequented by the public. These systems—bus, rail, and underground railways (tube or subway)—move large numbers of people around a city quickly or cheaply (sometimes both). To a wider extent, regional, national, and international airports carry out the same task.

Airplanes as High-Profile Targets

A number of prominent international airline hijacks in the 1970s brought terrorism into the public arena. Terrorist groups hijacked airplanes, taking passengers hostage and finding a country to land in that was sympathetic to its cause. On most occasions, the hijackers surrendered without any hostages being harmed, but some occasions resulted in the deaths of a number of terrorists and passengers. As terrorist bomb-making became more sophisticated, the need for hijacking became redundant. Instead, bombs carried in suitcases were used that could evade detection systems at airports. Perhaps the most destructive terrorist attack on a passenger plane was the Pan Am Flight 103 Lockerbie disaster over mainland Scotland in December 1988.

The attack on the World Trade Center attack in New York and the Pentagon in Washington, D. C., in September 2001 was a throw-back to the 1970s in terms of terrorism. The terrorists hijacked the planes in flight, but instead of directing the pilot to fly the plane to a destination, the hijackers themselves took over the controls and flew them into their intended targets (with one plane forced down short of its target to crash in Shanksville, Pennsylvania). Although security screening had improved vastly from the 1970s as far as detecting sophisticated bombs, it had become lax in preventing weapons such as blades or knives from being carried onboard.

Another result of the advancement in sophisticated bomb-making techniques was the ease in which the various forms of ground transportation became easy targets. Any form of mass transit relies on its speed and ease of access to transport people from one place to another with minimal hold-ups. With terrorists (both groups and individuals) becoming more extreme in their views and dispassionate in their targets, ground transportation has come to the foreground in the case for legitimate targets.

Ground Transportation

In their attacks on transport infrastructure, and public transportation in particular, in England between 1973 and 1976 and again between 1991 and 2000, the Irish Republican Army (IRA) targeted the rail network around the country and the London Underground (subway). There were 22 bomb threats and explosions on the national rail network and 16 on the subway. Other targets included buses (three), roads (four), bridges (two) and the English Channel Tunnel. There were also many bomb warnings that turned out to be hoaxes or were defused, all adding to disruption of the transport networks.

Perhaps the worst attack on public transport in England occurred on July 7, 2005, when a series of coordinated suicide attacks targeting civilians took place during the morning rush hour in London. Four Islamist home-grown terrorists detonated four bombs, three in quick succession aboard three London Underground trains and one on a double-decker bus, resulting in 52 civilians being killed (as well as the four bombers) and over 700 being injured. The explosives were homemade, organic, peroxide-based devices packed into rucksacks.

Paris, Madrid, Moscow, Tel Aviv, and dozens of other cities have also suffered similar attacks in

recent years. New York's commuter tunnels and bridges were also a target of a planned al Qaeda attack in 1993 and the New York subways were targeted in 1997. Japan suffered the first attack on public transportation using weapons of mass destruction in 1995 when a Japanese doomsday cult released sarin gas into the Tokyo subway system, killing 12 people and injuring over 5,000 people.

Modern terrorism seeks to cause indiscriminate violence on as large a scale as possible. The next avenue for terrorists may be the use of chemical or biological weapons as a means to cause mayhem, as public transport systems are extremely vulnerable to this kind of threat due to enclosed areas and large numbers of people. As well as harming people in the subway, germs or gases could spread to areas above ground due to movement of trains through tunnels and ventilation systems exiting at ground level. In contrast, air flight can offer more protection against such attacks.

In comparison to other forms of transport, airplanes make relatively few passenger transfers and stops. Most airports around the world are situated in controlled locations where access to airplanes from the terminal buildings is controlled by few entry points and strict security procedures involving passenger profiling, metal detectors, x-ray equipment, and armed guards. None of these can be easily transferred to buses and trains as delays to these services would be costly and detrimental to the purpose of mass transport.

Ground transportation systems are vulnerable targets to any would-be terrorist attack due to their many access points and lack of security procedures. Small amounts of explosive carried in rucksacks are completely undetectable and can cause extensive damage and fatalities when detonated in crowded train stations or public transport interchange locations. Even if no injuries to people occur, disruption to the public transit system in any city will have a serious impact financially, as well as a demoralizing effect on the public using the system.

Mass public transport in any city is crucial to the economic growth and development of both local and national economies. It also offers attractive targets to terrorists seeking publicity. As was shown in London in 2005, small amounts of explosives can cause maximum damage in confined spaces, not only to the traveling public and transportation operations, but also to a region's economy and the

public's expectation of government providing basic protection to its citizens.

The Search for Greater Safety

How can transportation systems be made more resilient to acts of terrorism without compromising the ease of access, frequency of travel, and travel time? The airline industry has gone to great lengths since the 1970s to increase security in its operations from the time one enters the terminal building at the place of origin until one leaves the terminal building at the destination. As mentioned already, it is relatively easy for the airline industry to achieve this but, as with all operations, human error means that mistakes will be made; nothing is foolproof.

Ground transportation systems are faced with a different set of criteria than the airline industry. No ground transport system can, or will ever be, terrorist proof. But there are a number of options that can be used to help prevent acts of terrorism on these systems. These have been developed over the last 30 to 40 years, mainly in England as a result of IRA attacks, but can be applied to any transport operation.

A program called Crime Prevention Through Environmental Design (CPTED), formulated in the United Kingdom, carefully analyzed every terrorist incident that occurred over this period. From this analysis, a number of preventive measures were developed and implemented that not only protected lives but also reduced disruption to the public transport network.

These measures included dedicated staff in each police department advising local businesses on design and construction issues resulting from information gathered on blast effects on various buildings; improved visibility at stations for camera surveillance; blast-resistant litter bins located within view of closed-circuit television; improvement in fencing and lighting (bombs were often located in poorly lit areas); closed-circuit television with increased police patrols and prompt police response; passenger communications systems in many locations; extra staff and patrols; training of staff in the event of a terrorist bomb-warning or event; and the involvement of the public in detecting unattended bags and parcels.

This type of response is only possible in long-term continuing terrorist campaigns but can be adopted



A relief worker stands amid debris from the fuselage of hijacked United Airlines Flight 175 on the roof of Five World Trade Center on October 25, 2001, during recovery efforts in New York City after the terrorist attacks of September 11, 2001.

as preventive measures in any large city that has public transport networks. These security measures had their desired effect, as IRA terrorist attacks moved to areas farther afield on the railway network and to switch boxes and rail lines rather than stations, culminating in fewer bombs and more bomb threats. As in any public transport system, some things will never be achievable. Passenger screening and examination of all briefcases and parcels will not be practically possible for public transit systems used by large numbers of people daily.

No matter how much time and energy spent by any government is consumed by the matter of safety for the traveling public, this must be balanced against the cost-effectiveness of such measures. To make a public transit system totally safe, a prohibitive amount of money would need to be spent, but this would inevitably lead to a slower and more inconvenient system, which would result in people abandoning its use.

It would appear that a new phase of terrorism with regard to transit systems is now beginning.

With the continuing advancement in personal communication by use of the Internet and mobile phones, small terrorist cells are able to keep in touch when carrying out any terrorist attack. With terrorist attacks being perpetrated by smaller terrorist cells with no obvious affiliation to any organization, no public transit system will ever be safe.

The airline industry can continually improve on its security due to passengers having time to spend at terminal buildings waiting for connections, although smaller regional airports may not offer the same security levels. Regional or local flights can be used as an access point to any terrorist activity. Ground transportation, on the other hand, can only offer an after-the-event appraisal. Images of terrorists can only be established after the act, or attempted act, of terrorism has taken place.

There is no doubt that surveillance measures discussed above will help the public feel more secure, while offering the security services a method of identifying suspects. However, there is also another way that may help prevent any large-scale fatalities in the number of passengers using a public transit system, but this would involve a move away from the current practices prevalent in older cities around the world.

Where a city has three different types of public transit systems operating (bus/subway; bus/rail; subway/rail), these systems usually operate as separate entities. As already mentioned, this results in confined spaces where explosive devices can cause maximum damage to both the traveling public and surrounding structures. The solution is in the form of a multimodal interchange where the different public transit systems can come together and provide a seamless interchange for passengers between the different forms. Examples of this kind of interchange already exist in a number of European and American cities where space, light, and facilities—in the way of retail outlets—as well as a number of safety measures including closed-circuit television and open spaces, offer the traveling public a safe environment within which to travel.

London has also shown, through both private and publicly funded redevelopment, how existing transit systems in old, established city centers can be designed and implemented. Broadgate, a privately funded redevelopment of Liverpool Street and its surrounding area, provided a modern intermodal transport link between the subway, national rail,

and buses. King's Cross/St. Pancras—once the site of a horrific fire back in 1987 when 31 people were killed—is now a multimodal interchange where subway (tube), national rail, international rail, bus services, taxis, and bicycle parking facilities deal with over 95 million passengers a year.

The Stratford Interchange in London, built as a primary hub for access to the 2012 London Olympic Games, is an example of where a new transport hub facilitated local regeneration. This interchange acts as a terminus for the Jubilee Line Extension (subway), Docklands Light Railway, and the Local Over-ground Railway, as well as an interchange with the National Railway, the Central line (subway), and local bus and airport coaches. It also has a new civic square, a high-quality bus station, cycle parking with good natural surveillance, and convenient drop-off and pickup points.

Transport systems will always be a target for any terrorists willing to further their own aims. With the provision of counterterrorist measures, together with open, expansive, and modern intermodal changes, the effects of any terrorist attack can be reduced and the public treated to modern, efficient, and inviting ways to travel on public transit systems.

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See Also: Airplane Disasters; Airport Passenger Terminals; Airport Security; Emergency Response Systems; Evacuation Planning; Freight Transport, Security Issues; Harbor and Port Security; Hazardous Materials Transport; Security, Transportation; Transit Safety; Tunnels, Safety and Security Issues in.

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3-C Planning Process

Transportation planning in the United States, which initially was highly localized, has evolved to become more regional in outlook today. A causal change agent of this evolution was passage of the Interstate Highway Act of 1956. Establishment of the interstate highway system linked communities and even states that previously had only minimal connection with each other. Cities, states, and the federal government all were careful to guard their own interests, while at the same time gaining an understanding of the need to work collaboratively on transportation-related issues.

To avoid the parochialism prevalent in many communities and to tap into the expertise found in these same jurisdictions, the 1956 highway act was followed by the Federal-Aid Highway Act of 1962. With this act came a federal mandate for urban transportation planning in the United States. Specifically, the act required that all 204 cities of the United States with populations greater than 50,000 develop and maintain a transportation plan. Passed during the time when urban areas were planning their interstate highway routes, the 1962 act resulted in a significant growth of urban transportation planning. The 90 percent federal funding for interstate highway projects was another motivating factor for locales to develop transportation programs and policies.

The 1962 act is also considered to be a landmark piece of legislation in that it required that planning in urban areas be "continuous, comprehensive, and cooperative" (3Cs) in order to qualify for federal funding. Cooperative was defined not only to include cooperation between the various scales of government (federal, state, local) but also between differing agencies at the same level of government. Continuous was defined as the necessity for periodically evaluating and updating the transportation plan. Comprehensive was defined to include 10 elements required under the 3C planning process.

All inventories and analyses required as part of the transportation plan included analysis of the following: (1) economic factors affecting development; (2) population; (3) land use; (4) transportation facilities, including those for mass transportation; (5) travel patterns; (6) terminal and transfer facilities; (7) traffic-control features; (8) zoning ordinances, subdivision regulations, building codes,

and the like; (9) financial resources; and (10) social and community-value factors, such as preservation of open space, parks, and recreational facilities, as well as preservation of historical sites and buildings, and environmental amenities and aesthetics.

Such a comprehensive list helped engender the mandatory cooperation between various agencies and levels of government. This approach to planning was required of urban areas that wished to receive federal funding. As urban areas were defined as regions, this act also helped spur the development of regional modeling.

Ultimately, the entities that became associated with this regional modeling and transportation planning were metropolitan planning organizations (MPOs). Comprised of transportation planners and representatives from local government, the MPO's mandate was to develop a four-year transportation improvement program, which was among the most critical functions of the MPO. The Bureau of Public Roads, which later became the Federal Highway Administration, worked with external collaborators to develop standardized planning methodology and transportation modeling.



Transportation planning involves evaluating, assessing, and designing transport facilities, generally highways, streets, and public transportation lines. The "L" trains in Chicago, shown here, are planned and developed by the Chicago Transit Authority.

The outcome of this work was the Urban Transportation Modeling System (UTMS), which was a four-step approach to transportation modeling. The variables in the model were trip generation; trip distribution; mode choice; and route assignment. Trip generation refers to the number of trips made per weekday per household and is dependent on household characteristics such as income and size. Trip distribution estimates the generation of trips and seeks to define such trips as home-to-work or home-to-nonwork destination, among others. For mode choice, a travel mode is selected as determined by household income, travel modes available, and travel mode costs. In route assignment, trips are assigned to the network. Ultimately, vehicle speeds are reduced and trips are assigned alternate routes.

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See Also: Federal Aid Highway Program; Highway Planning; Interstate Highway System; Metropolitan Planning Organizations; Regional Transportation Planning; Regional Transportation Planning Organizations; Transportation Planning; Urban Transportation Modeling System.

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to absorb shock, and a tread to provide traction. The use of compressed air as a cushion is what separates the modern (pneumatic) tire from older tires, which simply shielded wheels from damage. Nonpneumatic tires are still used for the wheels of things like lawnmowers and carts. The tire industry is one of the most important consumers of rubber, producing over 1 billion tires annually for over \$100 billion.

The National Highway Traffic Safety Administration (NHTSA) in the Department of Transportation, maintains publicly accessible databases of tire recalls and consumer complaints. NHTSA also maintains a database of ratings for 2,400 lines of tires for passenger cars, minivans, sport utility vehicles (SUVs), and light pickup trucks. The ratings reference the Uniform Tire Quality Grading System (UTQGS), which grades every tire on treadwear, traction, and temperature. Tire manufacturers are required to display the grades of their tires on the sidewall.

Treadwear compares a tire's wear rate to a control tire, which is assigned a grade of 100. The treadwear grade represents how long the tire lasted compared to the control tire. More than half of tires are graded 201–400, meaning they took two to four times as long to wear out as the control tire. Only 15 percent are graded below 200, and about a quarter are graded between 401 and 600. Safety concerns make it important that tires be replaced when the tread is less than 1/16th of an inch. The "penny test" is an old one that still works: Insert a penny into the tread (Lincoln's head first). If the tread does not cover any part of Lincoln's head, the tread is worn too low. Modern tires also have tread wear indicators that mark when the tire needs to be replaced. Tires should be rotated regularly to prevent uneven wear.

The traction grade rates the tire's ability to stop on wet pavement and is graded C, B, A, or AA (essentially an A+). Only one line of C-rated tires is sold in the United States. Seventy-five percent of tires are rated A for traction, with a small number (3 percent) of high-performance AA tires and a somewhat larger number (22 percent) of B-rated budget tires.

Temperature grades rate the tire's resistance to heat. Blacktop becomes especially hot in the summer, and in combination with sustained driving, this can lead to tire deterioration, tread separation, or blowouts. Temperature is graded with a simple A, B, or C. Most tires are graded A.

Tire Safety

Modern tires are ring-shaped covers for vehicle wheels and provide both traction with the road surface and a cushion to help absorb shock. Made of both natural and synthetic rubber, each tire has both a body, which contains compressed air

In addition to the UTQGS ratings, federal regulations require other information to be displayed on every tire, including the vehicle type for which the tire is intended (P stands for passenger vehicle), a three-digit number giving the width in millimeters from sidewall edge to sidewall edge, a two-digit number giving the ratio of height to width (with lower numbers, and thus shorter sidewalls, resulting in better handling on dry roads), an R for radial construction (the industry standard, though there were once other options), the diameter of the rim in inches, the load index indicating how much weight the tire can support, an M/S or M+S to indicate the tire has some mud and snow capability (which is true of nearly all radial tires), a letter rating indicating its speed rating, the Transportation Department tire identification number used for recalls or customer complaints, the tire ply composition and materials used, the maximum load rating, and the maximum permissible inflation pressure as mentioned above. The letter rating used for the speed rating indicates the maximum speed capability of the tire. In addition to these items, tires for light trucks (marked LT) list the maximum dual and single load and tire pressure and the tire's inflation limits and load-carrying capabilities.

Preventing tire failure, to minimize the possibility of accident, requires that tires be properly maintained. Basic tire maintenance consists of checking the tire valves and making sure they are capped and, on long trips or transporting unusually heavy loads, checking tire pressure at regular intervals. Additional safeguards include not overloading the vehicle, not pulling a trailer that is too heavy, and inspecting tires regularly for signs of wear or trauma, looking for cracks, embedded objects, uneven wear patterns, or loss of tread depth.

The tire information placard attached inside the vehicle by the car manufacturer—usually inside the trunk lid, on the glove box door, or on the vehicle door edge—specifies the vehicle capacity weight and often the gross axle weight ratings (which are always included in the user's manual). These indicate the maximum weight that can be carried by the vehicle and by the axles, respectively. Rubbing over curbs, striking curbs from the side, and running over potholes and objects in the road contribute significantly to tire wear as well.

To properly function, tires must be inflated to the correct pressure, which varies by tire and

vehicle. Maintaining proper tire pressure is necessary to avoid blowouts and flat tires; it also improves handling and fuel efficiency. Because most tires are sold with the intent of being used on more than one make and manufacture of vehicle, the tire's maximum inflation pressure is listed on the tire sidewall.

Prescribed pressure applies to a cold tire, one that has not been used in the last few hours. Correct tire pressure for each car model (which is measured in pounds per square inch and is easily measured with a gauge that attaches to the valve) is noted not only in the owner's manual but in the tire information placard. Too much pressure makes the tire more likely to blow out as a result of a heavy load or contact with a sharp edge or foreign object. Too little pressure impairs handling, exacerbates the effects of a slow leak, and increases the wear and tear on the (considerably more expensive) rims the tires are protecting.

Tires must also be properly balanced and aligned in order to keep the car from shaking while driving as a result of weight imbalances. Those imbalances can also cause a car to list to the left or right while driving. Wheel alignments, usually performed by a mechanic and requiring special equipment, adjust the positions of counterweights on the wheel that balance the weight of the wheel and tire assembly.

In snowy northern areas such as the Northeast and the Upper Midwest, many people use snow chains or snow tires for improved traction in the winter. Snow tires differ from regular tires in a number of ways. Their rubber composition is usually softer compared to other (all-season or all-weather) tires, providing better grip at cold temperatures. The tread is deeper, often significantly so.

In some places—the entire province of Quebec, for instance—use of snow tires is mandatory for the coldest months of the year. In other places, the use of snow chains is preferred. Snow chains are placed over the tires and so can more easily be taken on and off as the weather dictates. They increase the traction of the tire while reducing the speed (sometimes significantly) and fuel efficiency. Because snow chains do much more damage to the roads, their use is illegal in some areas.

Legal conditions vary significantly: Alaska permits their use whenever safety requires them in order to avoid skidding and sliding, but bans them during the warm months (April or May through

September, depending on the latitude); Colorado, on the other hand, requires them on certain posted roadways, and New York requires them during any declared snow emergency.

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See Also: Automobile Safety Systems; Automobile Tires, Nitrogen Inflation and; Passenger Van Safety; Trucks, Safety Issues and.

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Toll Roads, Private

Over the past 20 years, the private sector has reemerged as an important player in transport, not only in the provision of highway design and construction, but, increasingly, as a project initiator and a provider of facility financing, management, operations, and maintenance. The extent to which traditionally public transportation facilities are partially or entirely privatized is based on a confluence of fiscal, infrastructural, and political factors, but, given current trends, it will likely result in an even greater role for private transportation infrastructure consortia in the future—accompanied by an increasing debate over its appropriateness and propriety.

And, as facility tolling has increased in popularity as a strategy to fast-track project procurement and leverage sources of private investment that might not be otherwise available, the private sector has recognized the investment potential of these projects.

Background

Historically, the private sector has played a pronounced role in providing highway transportation infrastructure in the United States. As early as the late 18th century, private companies were building and improving roads for foot traffic, horses, and carriages, and were recouping their costs by charging users a toll. The first American toll road for motorized vehicles—the Long Island Motor Parkway, completed in 1911—was privately constructed, operated, and maintained. Public toll authorities only emerged as part of the "good government" movement early in the 20th century, largely in reaction to malfeasance and mismanagement in the private contracting and financing of the Brooklyn Bridge in New York City.

Beginning in the 1950s with the construction of the interstate highway system, direct federal, state, and local funding of interstate and state highway facilities—through the General Highway Fund, direct congressional allocations, or publicly issued debt—dominated highway financing. This persisted through the 1970s. However, a confluence of trends over the next quarter-century encouraged the increasing involvement of private entities in various phases of surface transportation facility procurement.

During the President Ronald Reagan administrations in the 1980s, there was a devolution to the states of many traditionally federal infrastructural responsibilities, laying the foundation for the cautious encouragement of public–private partnerships in the procurement of highway facilities in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the 1997 Transportation Equity Act for the Twenty-First Century (TEA-21), and the 2005 Safe, Accountable, Flexible, Efficient Transportation Efficiency Act: A Legacy for Users (SAFETEA-LU). Each successive act provided funding for states to explore increasingly privatized models of new highway provision and expanded highway capacity.

In addition, the Transportation Infrastructure Finance Innovation Act of 1998 and the 2012 and 2013 Transportation Investment Generating Economic Recovery (TIGER) discretionary grant programs expanded the range of federal funding options for surface transportation infrastructure projects of national significance. Highway transportation facilities—especially those designed to

be toll facilities—developed or expanded over the past 20 years have been increasingly public–private partnerships of an increasingly diverse variety.

At the same time that the federal government was pulling back from its historically dominant role in surface transportation facility funding, a series of recessions in the early 1990s, early 2000s, and 2008 and 2009, combined with a persistent aversion by states and the federal government to allocate non-fuel-related tax revenues (through the General Highway Fund) to the increasingly necessary maintenance of the country's highway infrastructure, presented private entities a number of opportunities to form partnerships with state, regional, and local transportation agencies to provide those services and, often, the supporting financing.

Compounding this political and fiscal retrenchment is the increasing congestion, age, and frailty characteristic of a significant portion of the U.S. highway transportation infrastructure. Not only has much of the U.S. highway system passed its design lifetime, but there has also been an accelerating shift of the country's population to its urban centers, putting enormous stress on urban highway systems and resulting in high levels of congestion and attendant air pollution. Increasingly, federal, state, regional, and local transportation agencies are looking to the private sector to accelerate the development of facilities to accommodate this increased capacity demand.

From Public to Private Toll Roads

The traditional public toll road is one that is conceived, financed, operated, and owned (if not maintained) by a public transportation agency. It generates a usage-based toll revenue stream that is managed by the sponsoring agency with rates set as the result of a transparent, public, political process. While maintenance and/or operation of these toll roads may be contracted to private concerns, these facilities remain under public control because decisions related to the creation of the facility, its financing, and the management of the resulting revenue stream remain under public control. A private partner may be reimbursed for operations and maintenance services by performance-based “availability payments” from the public partner, which would be derived either from toll revenues or from general fund allocations.

The degree to which a toll highway is considered “private” depends on the nature of the partnership

between the public sponsor and the private entity and, ultimately, whether the public sector controls the toll revenue stream, facility operations, and rate setting. A purely private toll road is a new or expanded facility that is conceived, financed, constructed, operated, and maintained by a private entity or consortium in response to market demand as a profit-making venture for the entity and its investors.

One example of the for-profit model is the 22-mile Camino Colombia Toll Road near Laredo, Texas, which was developed by Camino Colombia, Inc., to give truck traffic swelling as a result of the North American Free Trade Agreement (NAFTA) a direct connection between Interstate 35 and the Colombia Solidarity Bridge (Bridge 3) over the Rio Grande to Mexico. The \$90 million project was completed in 2000 but declared bankruptcy in 2003 due to lower-than-forecasted traffic volumes. It is now owned and operated as a free highway by the state of Texas. A more successful example of a purely private toll road is the Dulles Greenway, a 14-mile privately conceived, constructed, operated, and maintained extension to the publicly owned Dulles Toll Road in Loudon County, Virginia.

Purely private toll road projects are rare because of the size of the investment and the risk that toll revenues will be insufficient to cover project expenses and generate an acceptable return on investment. Most private toll roads are public facilities for which long-term operations and maintenance (O&M) leases—or concessions—are granted to a private entity in return for a single up-front payment and access to the revenue stream generated by tolling the facility. Technically, the public owns the toll road, but responsibility and uncertainty associated with managing the toll revenue stream are transferred to the private concessionaire. The public agency benefits from the option to allocate the up-front payment to other priorities, and the private entity benefits by gaining a long-term revenue stream with which to repay project equity and debt investments.

Controversy

The arguments made in favor of private toll roads derive primarily from those associated with the putative superiority of an unfettered free market economy to respond to transportation facility demand more efficiently than public-sector agencies. Proponents of private toll facilities argue that a

free market is best situated to respond to state needs for providing additional or renovated capacity and facility operations, management, and maintenance. While federal and state transportation budgets are subject to ebbs and flows of political and fiscal will, the private sector responds to the desire of capital to find the best return on its investment, in theory. In this view, toll rates for these facilities are set best not by state regulators but in response to competitive market signals sent by user demand for the transportation capacity supplied by the facility.

In spite of the long-term risks characteristic of such projects, highway infrastructure development and management often meet those profit goals. Private transportation consortia often can leverage not only sources of capital unavailable to public-sector sponsors (for example, private equity stakes and market capital), but also may be able to develop or apply innovative management, construction, and operations technologies (for example, automatic tolling) to which public sponsors may not have access.

The quasi-permanent O&M concession granted by a public transportation agency to a private concern—often for as long as 99 years—is necessary, it is argued, to provide the concessionaire with time not only to recoup its equity investments and repay debtors for the original facility construction but also to compensate it for managing facility operations, maintenance, and new construction over the term of the concession. The term of the agreement is also necessary to mitigate the long-term risk associated with the uncertainty of facility usage and its toll revenue stream.

Many critics of private toll roads argue that tolling, in and of itself, has undesirable equity and fairness consequences, such as imposing additional transportation costs on those least able to afford it. (However, while costs for the individual driver may, indeed, be higher for a toll-financed highway, a recent study by Schweitzer and Taylor indicated that the low-income resident population pays more out-of-pocket for a similar facility financed by more egalitarian, sales-tax-based means.) They also point out that non-compete clauses often included in concession agreements unfairly favor the private facility by restricting expansion and/or improvement of public highway capacity in the vicinity of the toll facility.

However, issues of the public interest and of public versus private decision making generate the most controversy over the development and management

of private toll facilities. The granting by a public-sector transportation agency of an O&M concession to a private entity effectively removes from public debate and accountability issues such as the level at which facility tolls are set, the uses to which that revenue stream are put, and the quality of O&M services. More broadly, private ownership of transportation infrastructure interferes with broader transportation policy making and planning.

Many of these concessions have lifetimes that span several generations, and critics argue that awarding such contracts does not adequately address the best interests of future generations of facility users. Furthermore, studies have been conducted that suggest that the retirement of private debt, to which the toll revenue stream is directed during the concession, may occur in far less time than the term of the contract, leaving the private entity reaping far greater profits than it is due.

A controversial example of this sort of agreement is the 99-year O&M concession for the publicly owned Chicago Skyway, an aging and financially troubled 7.8-mile toll facility, which was granted in 2004 to a private operating consortium for \$1.83 billion.

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See Also: Automated Road-Pricing and Toll-Collection Systems; Construction Management; High Occupancy Toll Lanes; Highway Finance; Intermodal Surface Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Transportation Efficiency Act; Transportation Equity Act for the Twenty-First Century.

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Tourism

Tourism is a major contributor to economic development in many regions of the world. The term *tourism* is used to describe the following:

- Tourists, the individuals who engage in voluntary return mobility
- The tourism industry, those firms, organizations, and individuals that enable tourists to travel
- The broader social and economic phenomenon of tourism, including tourists, the tourism industry, the people and places that comprise tourism destinations, and the impacts of tourism on generating areas, transit zones, and destinations

Although widely perceived by the layperson in terms of leisure or vacation travel, tourism is defined technically in terms of the voluntary, temporary mobility of people for nonemployment purposes. This article outlines the economic significance of tourism, employment contribution, and implications of partial industrialization and impacts.

In distinguishing tourism from other types of population movement, several factors are important. Tourism is voluntary, return travel and includes neither the forced movement of people for political or environmental reasons nor permanent migration away from what was their home environment, although the distinction between tourism and migration is sometimes blurred because of extended return travel away from a home environment in another country. The statistical definition of tourism therefore depends on determining

factors of time (how long people are away from their permanent place of residence, usually less than a year) and distance (how far people have traveled or whether they have crossed jurisdictional borders). These considerations are vital in any assessment of the economic impact of tourism.

Global Economic Significance

According to the United Nations World Tourism Organization (UNWTO) in 2012, international tourist arrivals reached over 1 billion for the first time, up from 25 million in 1950, 277 million in 1980, and 528 million in 1995. Given that an international trip can generate arrivals in more than one destination country, the number of trips is lower than the number of arrivals. Although international inbound tourism is usually the primary national policy focus because of its role in international trade and business, at a global scale over 80 percent of tourism is domestic.

The role of domestic tourism in regional economic development policy therefore means that it is usually the focus of state, provincial, or regional governments. National governments tend to focus on attracting international tourist arrivals and, in some cases, seek to limit outbound tourism growth because of the economic loss it represents to a country's economy. However, some national governments do support domestic tourism initiatives as part of regional development strategies.

Even though the relative proportion of tourism's contribution to international trade in services has declined since the 1980s, tourism remains an extremely significant contributor to the global economy. According to the UNWTO, tourism ranks as the fourth-largest economic sector in the world after fuels, chemicals, and food, and contributes an estimated 5 percent of global gross domestic product (GDP), and 6 to 7 percent of employment (direct and indirect).

International tourism's export value, including international passenger transport, was estimated at \$1.2 trillion in 2011, accounting for 30 percent of the world's commercial service exports or 6 percent of total exports. Tourism is one of five top export earners in over 150 countries, while in 60 countries it is the number one export sector. It is also the main source of foreign exchange for one-third of developing countries and one-half of least developed countries (LDCs).

International tourism numbers have continued to increase since World War II and have only shown short-term decline or leveling off in growth at times of economic crisis, often related to energy and/or political crises. The UNWTO predicts the number of international tourist arrivals will increase by an average 3.3 percent per year between 2010 and 2030 (an average increase of 43 million arrivals a year), reaching an estimated 1.8 billion arrivals by 2030.

Most growth is forecast to come from the emerging economies and the Asia-Pacific, and by 2030 it is estimated that 57 percent of international arrivals will be in what are currently classified as emerging economies. At the same time, domestic tourism, especially in the emerging economies, is also expected to grow.

Contribution to Economic Development

Tourism has become increasingly important as an economic development mechanism since the 1970s as a result of globalization and restructuring, which has affected urban and rural economies in the developed world. For example, the European Union's European Regional Development Fund, which was established in 1975, utilizes tourism as a development strategy because it is perceived as being highly labor intensive and a counterbalance, along with other service industries, to job loss in the agricultural and manufacturing sectors. Tourism is also important to the economies of many small island states and LDCs, where there are limited economic development options.

There are a number of reasons why tourism is perceived by policy makers as a potential economic development mechanism. Of great significance are the diversity of the businesses that make up the destination product and the travel component provides for circulation of tourist expenditure through a number of different sectors. The supply chain to tourism businesses can also provide significant employment and economic opportunities, particularly in areas such as the provision of food for tourists, which flows through to the agricultural and horticultural sectors. In the developing country context, tourism may therefore also create business opportunities in the informal economy, as the barriers to entry and start-up costs are relatively low.

Tourism is also regarded as a labor-intensive industry. This has become an important issue where economic restructuring has led to unemployment

in traditional industries and where there are few employment alternatives. In the less developed countries, institutions such as the World Bank and the UNWTO have argued, tourism is important in tackling poverty given the sometime lack of development opportunities. Of particular importance is the relatively low skill requirement of some tourism employment, such as hotel room cleaning and restaurant service, which therefore also implies low training costs for government and businesses. The service dimension of tourism also potentially creates employment opportunities for women that otherwise may not exist.

Economic development through tourism is established not only by the stock of its built capital (for example, transport and energy infrastructure, water supply, and sanitation), or of its natural capital (that is, national parks and biodiversity), but also by its human capital (that is, skill, knowledge, education) and social capital, especially the connectedness of entrepreneurs to a destination. Therefore, tourist destination development can have important economic impacts on other sectors. The enabling role of tourism for business travel (that is, the role of hotels, hospitality, conference centers, and the tourism transport system) in facilitating business and trade networks is an often overlooked indirect contribution of tourism to economic development.

Employment

The employment opportunities generated by tourism have aroused substantial debate with respect to their true value to destination communities in comparison with other industries. Although a tourism-based economy can provide employment for people with limited training and skills, many of these part-time and casual jobs also pay low or minimum wages that may result in a population of working poor.

The relative value of tourism employment is also often contested because many of the jobs are regarded as being relatively low skilled. Although this has both advantages and disadvantages, tourism therefore provides opportunities for income generation in entry-level positions for those with low skill or language levels, thereby creating significant opportunities for migrants. Employment in tourism is also highly gender specific, especially when the empirical and emotional labor of hospitality is often regarded as women's work in many societies.

Another characteristic of employment in tourism and hospitality is the extent of variable demand over time and space. As a service industry, the tourism labor force has to be assembled at the point of consumption and also be sufficiently flexible to meet daily, weekly, and seasonal fluctuations. For example, at the microlevel, consumer purchase of lunch and evening meals leads to a high degree of part-time and casual employment in the restaurant sector to meet peak demand. The macro-level seasonal demand leads to substantial fluctuations in employment availability, which is often met by the hiring of employees from outside the destination area.

The extent to which seasonal tourism demand generates temporary migration and working-holiday flows, rather than use of local labor, is contingent on the location and the nature of tourism development, with a prime consideration being the capacity of labor to be transferred from other

sectors to tourism at periods of peak demand. For example, although tourism is economically significant in many rural areas, where peak demand for labor in agriculture is simultaneous with high levels of summer tourism demand, it can be extremely difficult to supply adequate labor from the destination region. In contrast, where peak tourism demand is in winter, as in some alpine areas, then agriculture and tourism may be much more compatible economic development mechanisms.

Seasonality

The phenomenon of seasonality is arguably one of the main issues in understanding tourism's potential contribution to economic development, because it affects not only employment but also tourism businesses. Seasonality is the result of the characteristics of the tourist-generating area and the destination. In terms of the generating area, key factors are timing of legislated holidays, especially



Tourists photograph lions resting in the Selous Game Reserve in the south of Tanzania in 2009. Most tourism growth is forecast for emerging economies such as those found in Africa and in the Asia-Pacific region, with 57 percent of international arrivals occurring in such countries by 2030. Tourism's presumed potential for poverty alleviation may not be realized, however, as research on the economic effects of the tourism industry in Kenya, Tanzania, and Uganda has found that most benefits go to those who are already wealthy.

school holidays, religious and cultural holiday conventions, and weather conditions.

Destination seasonality is strongly influenced by weather conditions and the overall resource availability for certain types of attractions, such as snow for skiing or the availability of particular scenery, as in the case of changing leaf colors for fall tourism in the northeastern United States. Although some forms of tourism, such as business travel, are affected by seasonal fluctuations in demand, seasonality affects nearly all aspects of tourism business and presents one of the greatest challenges at both a firm and destination scale.

Partial Industrialization

The nature of the tourism industry means that many sectors that make up tourism (for example, transport, visitor services, accommodation, restaurants, museums, art galleries, and attractions) have different business goals because they serve both tourists and nontourists. The situation in which the customers of many tourism businesses are nontourists is termed “partial industrialization,” and this is the condition by which only certain firms and agencies that provide goods and services directly to tourists are regarded as part of the tourism industry.

Partial industrialization is important for reasons including cooperation, management, policy, and strategy, as well as economic statistics. For example, the notion of partial industrialization reflects the statistical development of Tourism Satellite Accounts, which are now extensively used to measure tourism’s economic and, to a lesser extent, environmental impact.

From a strategic perspective, one of the consequences of the partial industrialization of tourism are its significance for tourism development, marketing, coordination, and network development. For example, although many segments of the economy benefit from tourism, only those organizations that perceive a direct relationship to tourists and tourism producers usually become directly involved in cooperative tourism development and marketing. Therefore, external inducements, such as promotion schemes established by government at no or minimal cost to individual businesses, or regulatory action such as compulsory business rating tax for promotion purposes, are often required before linkages can be established with those businesses

that do not normally regard themselves as being in the business of tourism. However, the significance of networks for tourism applies across all subsectors no matter what the size of the firm or sector. It is only in those limited numbers of firms that continue to offer package tours to tourists within their own vertically integrated business structures that the role of networks is downplayed.

The concept of partial industrialization highlights that the tourism industry and destinations can be framed as loosely articulated groups of suppliers who link together to deliver the overall trip and destination products, as well as knowledge transfer.

Three different main types of networks can be identified. First, innovative networks where businesses share complementary assets, such as airline alliances. Second, networks of businesses sharing in the marketing knowledge of specific customer segments. This includes the vertical and horizontal integration strategies of larger companies, as well as the knowledge management associated with special-interest tourism products, such as medical tourism, for which there are multideestination industry associations. Third, networks coordinating complementary assets at the destination level. This includes destination marketing alliances and promotion and the development of new products and innovations. Tourism businesses then strategically position themselves within such networks to leverage from innovation and future organizational configurations.

The contemporary tourism industry is characterized by a small number of large, often multinational firms with economies of scale, wide distribution, and a global network, taking a high-volume, low-profit approach, particularly in the aviation and accommodation sectors, and large numbers of small firms that are often niche-differentiated operators focusing on particular destinations or products, independent of external control and not influencing market prices.

Many destinations are therefore dominated by micro-businesses of fewer than five employees that are often owner operated. Such small tourism firms are often a significant tourism policy focus of governments and economic development agencies, especially in more peripheral regions that are undergoing economic restructuring and transition economies. Although such small businesses are often criticized by larger operators as not being

“real” businesses, particularly as their owners may be participating in tourism for lifestyle reasons, such firms are extremely significant because they play an important role in rapidly responding to peak tourist demand and rapidly diffuse income into the destination economy through strong backward linkages.

Criticisms

Tourism's contribution to economic development has been criticized because of its less positive environmental and social impacts, while, in some cases, its economic and employment contribution has not been as great as policy makers believed. For example, research on tourism in Kenya, Tanzania, and Uganda indicated that hotels, restaurants, and the transport industry provide below-average shares of income to poor households compared to other export sectors. In some cases, it has been suggested that tourism may be disproportionately beneficial to the already wealthy and fail to assist the poorest members of society who do not have the capital or language skills to cater to international tourists, thereby reinforcing already existing inequalities.

One of the difficulties in assessing tourism's contribution to regional development, and to poverty reduction and alleviation in particular, is that while tourism has been promoted in the economic development community for over 40 years, the mid- to long-term relative contribution of tourism to regional development strategies remains poorly evaluated. For example, in the LDC context there has been greater interest by international development agencies in advocating tourism and initiating projects than in the critical assessment of their consequences. These empirical weaknesses have only been reinforced by increasing awareness of tourism's contribution to climate and environmental change, and therefore concerns over its long-term economic contribution, particularly for those island, coastal, and alpine destinations that are most dependent on tourism.

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See Also: Airline Marketing; Economic Development; Noncommuter Travel; Ocean Cruise Industry; Ocean Passenger Travel; Recreational Travel; Recreational Vehicles; Scenic Roads and Parkways; Travel Destinations.

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Traffic Calming

In all facets of transportation planning, the automobile asserts its dominance. From highways to arterial and collector streets and down to local roads, infrastructure design has placed the automobile at the apex of the transportation hierarchy. Well-paved roads with wide lanes, along with incomplete or nonexistent sidewalks, crosswalks, and bicycle lanes, have resulted in a sprawling built environment.

Yet, until the 20th century, the design of communities was oriented primarily around the pedestrian. Characterized by mixed land use, a grid of connected streets, and moderately high densities, traditional land use patterns were noted for their connectivity and accessibility. As a result, these types of communities are deemed “walkable” in today's parlance.

Following World War II and beginning with the widespread construction of the suburbs and the interstate highway system in the 1950s, this walkable neighborhood design was increasingly replaced by dependence on the automobile. Cul-de-sacs were substituted for connector roads, blocks became larger, and land uses were separated by inflexible zoning codes. More than just discouraged, pedestrian activity became next to impossible. Where it

did occur, the dangers incurred by traversing the streetscape on foot were daunting.

Efforts to mitigate the risk factors associated with pedestrian travel are frequently associated with the concept of traffic calming. Encompassing a series of design principles, the primary objective of traffic calming is the reduction of automobile speed and volume along residential streets.

Traffic calming devices may fall under the following four broad categories based on their design. First, vertical deflections are elevated sections of roadway that force drivers to slow down. A common type of vertical deflection is the speed hump, which is a raised area in the roadway pavement extending across the entire road. Raised crosswalks and speed tables also serve as examples of vertical deflections. Second, horizontal deflections, a second category of calming, alter the street width to discourage through traffic and reduce traffic volume. Chicanes are a common approach to horizontal deflection and are created by building out curb lines. Roundabouts and traffic circles also serve as horizontal deflections on busier streets. Third, narrowings are roadway segments that are narrower than the overall width of the street. One example is the “neckdown,” which is created by narrowing the street and widening the sidewalk. Fourth and finally, speed zoning is a section of street with a lower maximum legal speed than the limit for the rest of the roadway.

Additional traffic calming devices include the following: bus bulb, a widening of the sidewalk at a bus stop location so that buses remain in the travel lane when stopped at the bus stop; pedestrian refuge, a small island placed in the center of a two-way street that separates traffic and enables pedestrians to cross the street in stages; and roadway color/texture, the use of materials that introduce surface texture to the roadway, such as paver stones, bricks, or stamped asphalt.

Goals of Traffic Calming

In all cases, reducing traffic speed serves as the ultimate goal. In determining whether a specific roadway has a speeding problem, the 85th percentile speed, or the speed below which 85 percent of all traffic travels, is typically utilized.

Additional objectives of traffic calming include protecting neighborhoods from unwanted through traffic and increasing road safety. As noted by John Laplante and Barbara McCann, minimal reductions



Unlike the speed bump, the speed hump, like the one shown here, is less aggressive and more often used in residential areas to slow traffic. Even small speed reductions can lead to substantially higher rates of pedestrian survival in accidents.

in speed can have profound impacts on safety. A pedestrian struck by a car traveling 20 miles per hour has an 85 percent survivability rate. At 40 miles per hour, the survivability rate for the pedestrian plunges to only 15 percent.

A reduction in speed for most trips around town would add only a few minutes to the length of the trip but could exponentially increase safety for all nonmotorized users of the roadway. In fact, an increasing concern of transportation planners is the effect of roadways on animal populations. Reducing traffic volume and flow not only protects pedestrians and bicyclists, it can also reduce traffic-related mortality rates for many animals that are put at risk by the built environment. Continued decentralized growth and suburban sprawl has extended the human-dominated landscape into previously rural environs. The benefits of traffic calming therefore include improvement of living conditions for all inhabitants of an area.

The historic precedent of present-day traffic calming dates back to the 1940s and 1950s, when street closures and diverters were used to control traffic. However, it was not until the 1991 passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) that traffic calming received

national attention. Considered a landmark piece of legislation, ISTEA required transportation agencies to prove that there was no alternative to a project catering to cars before another road could be built.

Further, the act endowed states with the power to put federal funds where they are most needed. As a result, states could decide to transfer funds from highways to mass transit. Also, the provisions of the act required states to set aside a portion of their federal funds for use on community amenities, such as pedestrian or bike facilities. Thus, the singular dominance of the automobile was challenged through this historic legislation that was succeeded by the 1998 Transportation Equity Act for the 21st Century (TEA-21) and the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).

In addition to legislative support of traffic calming, the success of such programs is also dependent on public acceptance. Without the backing of the community in which the traffic calming is being implemented, these tactics may serve as a source of conflict. Traffic calming devices are also not guaranteed to improve conditions, as personal choices still take precedence over infrastructure changes. For instance, the construction of a raised crosswalk cannot guarantee that motorists will slow down or that pedestrians will cross in the crosswalk.

Several disadvantages have been cited in regard to installation of traffic-calming treatments. For example, snowplowing and street cleaning may be hindered, and emergency response time may be affected. Some motorists will choose to avoid roadways with calming devices, thereby increasing traffic on adjacent roads. Some traffic calming measures can affect drainage, and their construction and maintenance may be relatively expensive. Lastly, the noise of vehicles going over raised crosswalks or speed humps may disturb nearby residents, and emissions for a road calmed by speed humps may be higher than a noncalmed road.

Despite these concerns, the advantages of traffic calming associated with improved safety, reduced vehicular speed and volume, and improved quality of residential life is difficult to refute. As a result, an ever increasing number of communities are implementing traffic calming treatments to their roadways. These self-enforcing measures are particularly beneficial to nonmotorized users of the street and can deliver desired changes in travel behavior.

The total annual vehicle miles traveled in the United States increased nearly 40 percent between 1990 and 2010, and a staggering 169 percent since 1970. With Americans fast approaching 3 trillion vehicle miles traveled annually, there is an ever increasing need for roadways that accommodate all users, not just those in motor vehicles. A comprehensive traffic calming program and an integrated traffic management approach can substantially benefit all users of a roadway and return the streetscape to a more walkable form.

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See Also: Complete Streets; Environmental Impacts; Livable Streets; Pedestrian Safety; Pedestrian-Friendly Design; Road Diets; Road Surface Marking and Markers; Sidewalks.

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Traffic Congestion

Traffic congestion can be understood as the process by which the number of vehicles on roads exceeds their capacity. Congestion can slow down or stop the flow of traffic altogether, leading to longer and more unpredictable travel times, as well as a host of economic, social, environmental, and infrastructural costs.

The causes of congestion can vary, from site-specific contexts in which driver behavior or local circumstances may slow or impede traffic flow to broader, systemic conditions in which the number of vehicles using a roadway network consistently

exceeds its carrying capacity. In this light, traffic congestion has been attributed to low-density, automobile-reliant forms of development. It has garnered attention from multiple levels of government, as well as business and private-sector groups, non-governmental organizations, and advocacy groups.

Researchers argue that the costs of congestion are increasing. Longer travel times create additional financial costs for commuters, such as lost work hours, as well as gas and vehicle maintenance costs. Observers also note growing costs for specific industries, such as logistics and construction, as well as losses for municipal, regional, and national economies, resulting in part from the aggregation of costs from delays as well as the relocation of businesses to areas with lower levels of traffic congestion.

A number of other costs arise from traffic congestion. These include health and ecological problems related to greater concentrations of vehicle emissions, the possibility of increased accident rates, and mental stress on drivers and passengers. Municipalities and other levels of government also face growing infrastructural costs, as well as growing planning challenges because of unpredictable aspects of increased traffic congestion.

Responses vary but have increasingly reflected greater interest in regulating vehicle traffic and implementing taxes, tolls, and other revenue tools to pay for the maintenance and expansion of roadway networks. Technological tools have also been deployed to coordinate traffic management across larger geographic areas.

Congestion in Context

A growing number of researchers, policy makers, and industry groups have attempted to measure the rate and impact of traffic congestion. Methods vary, but, in general, traffic congestion is related to length of travel time and costs of delays (on individual vehicles, within specific industries, or across regional and national economies). Congestion occurs as roadway capacity is approached or surpassed. Roadway capacity itself is based on a “reasonable” amount of time in which a vehicle is expected to travel along a section of roadway, according to the U.S. Transportation Research Board.

A number of factors contribute to growing rates of traffic congestion. In particular, the number of vehicles on roadway networks is considered to be the most significant variable. In turn, this has been

linked to economic and population growth. Rising gross domestic product (GDP) growth rates over the past several decades, for instance, have been associated with higher rates of automobile ownership. Population growth, too, has contributed to a concomitant increase in car ownership and use.

In the United States, the number of vehicles grew from approximately 74 million in 1960 to more than 240 million by 2010, with the number of vehicles surpassing the number of drivers from the early 1970s onward, according to the U.S. Department of Transportation’s Federal Highway Administration (FHWA). The number of drivers increased from 84 million in 1950 (out of a total population of 180 million) to 220 million by 2010 (out of a total population of 309 million). Vehicle ownership rates and distances traveled by drivers have increased, while occupancy per vehicle has decreased over the past 40 years.

In the United Kingdom, the number of passenger cars per inhabitant has also grown, from slightly over one in three in 1990 to nearly one-half by 2009, according to data from the European Union. The number of registered vehicles grew from 4 million in 1950 to more than 34 million in 2009, according to the UK Department for Transport. These data align closely with rates for the broader European region, with higher rates of vehicle registration in western Europe compared with eastern Europe.

More recently, however, there are varying perspectives on the registration and use of vehicles in different jurisdictions. Citing the global economic crisis of 2007 to 2008, some observers have noted declines in vehicle registration rates, drawing connections with reduced incomes and rising fuel costs. In the United States, for instance, traffic congestion rose by 22 percent between 2012 and 2013, while in Europe congestion declined by 18 percent, according to the U.S.-based traffic technology firm INRIX.

Decades of growth in the numbers of vehicles on roadway networks (which in many jurisdictions have seen little to no expansion in recent years) have contributed to both the intensity and rates of incidence of traffic congestion. Some observers cite this lack of growth in roadway networks as a contributor to congestion, while others have drawn different conclusions, emphasizing the design of roadways and the form of urban and suburban development as more significant influences. Other, more localized causes of traffic congestion include

poor weather conditions, intersecting infrastructure networks (such as railway crossings), and poor construction and maintenance.

Roadway design may also contribute to congestion. Specific elements such as freeway-to-freeway interchanges, on-ramps and exit ramps, and lane reductions or mergers may intensify or cause bottlenecks. Bottlenecks from these particular components now contribute more to congestion than an overall lack of roadway capacity (through length or number of lanes), according to the FHWA.

Planners and policy makers are paying greater attention to the built environment and its relationship to traffic congestion. Automobile-based transportation planning, combined with low-density residential development, have been connected to one of the predominant forms of urban expansion over the past 50 years, leading to conditions of sprawl.

Measuring Congestion and its Costs

Increasingly, travel time reliability measures are used to determine not only rates of congestion but also to understand variations among seasons, during different times of the day (such as during peak and off-peak hours), and day-to-day variations. Two specific measures of congestion include the Travel Time Index and the Planning Time Index used by FHWA.

The Travel Time Index compares travel times for specific distances between peak and “free-flow” periods to help determine the average extra time required for peak-hour trips. The Planning Time Index is a ratio used to determine the total amount of time that should be allocated for travel to avoid arriving late 95 percent of the time (or one weekday per month). Congested hours reflect the average number of hours in which roadways are congested



A recent study of traffic congestion in Asian cities ranked several metropolitan Indian areas within the top 10 for worst traffic. It is estimated that 90,000 people die from road accidents every year within India; however in 2007, more than 130,000 people died on India roadways, overtaking China's similar high fatality statistics.

(that is, traffic moves at speeds below 45 or 50 miles per hour), often expressed per day or weekday.

Other measures of congestion include wasted hours, or time spent idling, and wasted fuel, or amounts of fuel lost while idling in traffic. These are often measured as a way to determine a series of direct and indirect costs associated with traffic congestion. Although estimates and interpretations of the costs of traffic congestion can vary widely, there appears to be a shared perspective across academic, government, and business observers that the negative effects of congestion are increasing—and will continue to increase without more direct forms of intervention to reduce or manage traffic volumes.

Time lost by drivers is one of the most prominent ways of measuring costs, as are fuel costs, and wear and tear on their vehicles. In 2011, urban Americans spent 5.5 billion hours in traffic (averaging more than a week per commuter), up from 1.1 billion hours in 1982, according to the Texas Transportation Institute (TTI). Traffic congestion led to nearly \$3 billion in wasted fuel (or 19 gallons per automobile commuter). The total costs of congestion rose from \$24 billion in 1982 to \$121 billion in 2011. These figures include lost time and fuel, as well as pollution costs.

In the United Kingdom, direct costs of congestion totaled more than \$6.4 billion, or more than \$700 per household, in 2011, according to an INRIX study produced for the Centre for Economics and Business Research. The same study noted similar household costs for France and Germany.

In Canada, direct costs can reach up to about \$3 billion annually, according to the Canadian federal transportation ministry. However, estimates vary widely, with some observers pegging direct costs for commuters in the Greater Toronto Area alone (the largest metropolitan urban region in the country) at \$2 billion to \$3 billion.

Industries particularly vulnerable to increased rates of traffic congestion include logistics, construction, agriculture, and retail and wholesale trade. In the United States, traffic congestion costs the construction industry up to \$23 billion a year, because of delays in project completion stemming from late material shipments and lost labor time. Congestion costs the trucking industry upwards of \$27 billion a year in wasted time and fuel.

Often, these increased costs are passed along in higher prices for consumers. For instance, in the

United Kingdom, INRIX research traced a rise in consumer costs resulting from shipment delays and lost labor totaling more than \$160 per urban household per year.

Aggregate costs of delays and lost time also affect municipal and regional economies. Some researchers have examined how traffic congestion may lead to greater costs for businesses as they relocate to more accessible locations, losing out on agglomeration benefits, paying higher wages to compensate for longer commute times, or facing declining productivity.

In the Greater Toronto Area, one study found that the region's economy loses more than \$2 billion a year from indirect costs of congestion. In the United States, the Department of Transportation estimates that congestion costs the national economy \$200 billion per year.

Emerging research on the health effects of traffic congestion reflects a range of additional costs. In one study by researchers at the Harvard School of Public Health, air pollution from congestion in 83 U.S. cities was cited for causing more than 2,200 deaths annually in 2010 (but predicting a decline to 1,900 annually by 2030), totaling about \$18 billion from premature mortality. Pollutants from traffic congestion have also been associated with premature births and low birth rates.

However, congestion studies in Europe and the United States have also predicted declines in pollutants over the next two decades, even as the numbers of vehicles grows, resulting in large part from improvements in fuel efficiency.

Longer travel times in automobiles have also been linked with reduced physical activity, which can lead commuters to greater risk for heart disease and diabetes. Stress and isolation have also been attributed to increased traffic congestion by the Ontario College of Family Physicians.

Drivers may also be at greater risk of being in traffic accidents, in part because congestion causes them to drive at uneven speeds in high traffic density. Nonrecurring congestion (due to temporary disturbances) is also correlated to 40 percent to 50 percent of accidents, according to the American Automobile Association (AAA).

Traffic congestion can also contribute to increased costs of other elements of urban infrastructure. Emergency response vehicles may face longer or more variable response times from congestion. As a

result, some municipalities have increased the number of fire or ambulance stations to compensate.

Spillover, or traffic infiltration, is also difficult to anticipate or manage. As main roadways or highways become congested, smaller roads see increasing amounts of traffic, as well as different types of traffic, as drivers seek alternatives. Conflicts can arise in municipalities that see a greater presence of transport trucks in residential areas, for example. The increases in both scale and complexity of roadway networks make it difficult for individual municipalities to address systemwide conditions.

Debates

A number of tensions have emerged among researchers and policy makers with regard to measuring, defining, and responding to traffic congestion. Some are related to debates over the effects of urban sprawl, while others address the emphasis on the automobile in research and responses. The Texas Transportation Institute (TTI), for instance, has issued a formal response to criticisms from Todd Litman, a planner with the Victoria Transport Institute, over its methodology and findings. The nonprofit organization, CEOs for Cities, also challenged the TTI for overestimating congestion costs and not addressing specific costs of urban sprawl in relation to transportation.

Responses

Part of the difficulty in responding to greater incidences of traffic congestion has to deal with temporal and spatial conditions. Congestion can be somewhat unpredictable or inconsistent, requiring greater understanding of peak road usage times and seasonal variation. As well, the effects of traffic congestion can extend beyond local or municipal boundaries and have unanticipated consequences in other road networks as drivers seek alternative routes. Cross-jurisdictional effects make it difficult to coordinate effective responses across varying levels of governments or among different public agencies.

Roadway expansion, through the extension or creation of new highways or roads, or the construction of additional lanes, may alleviate traffic congestion in the short term. Modifications to reduce impediments to vehicles may also improve traffic flow. However, many analyses show the prospects for reducing congestion through increased capacity are limited. Additional capacity can actually lead to more vehicles on roadways. (This is a result of latent

demand, which may be briefly alleviated through expansion.) Longer-term effects can be commuters moving farther away from their workplaces, increasing travel distances, and, eventually, leading to greater congestion at a later time.

Responses vary by region and level of government. However, a number of recent initiatives reflect greater efforts to integrate responses across jurisdictions, provide additional funding for roadway infrastructure (often through tolls, taxes, or other fees), and modify planning and development practices for urban metropolitan areas.

Transportation-specific revenue tools can include road tolls, fuel taxes, parking levies, and municipal or regional sales taxes. These are often developed with an eye toward recovering infrastructure costs directly from users themselves. The European Commission (EC) supports taxes and tolls among its member states to build and maintain trans-European infrastructure. Supporting principles of user-pay and polluter-pay, the EC has developed directives on vehicle and fuel taxes, as well as tolls and time-use charges for heavy-use vehicles, but not private automobiles, light commercial vehicles, or motorcycles. Member states have coordinated transnational networks for electronic use charges under this system.

In the United Kingdom, the city of London has introduced a congestion charge to be paid by most vehicles in the central city. Some exemptions are permitted, including cars that emit low levels of carbon dioxide as well as specific types of electric and hybrid vehicles.

The United States has more than 5,300 miles of toll roads and highways. During the 1980s and 1990s, the federal government renewed support for developing tolls as a means of funding the maintenance or expansion of interstate and other roadway networks during a period of reduced public spending. The U.S. Government Accountability Office is also considering allowing greater private-sector involvement in building and operating toll roads, although earlier projects in different states have had poor or mixed results. The GAO has also raised concerns over equity and accessibility, based on driver income levels and geographic location.

Types of toll roads can include specific express toll lanes or high-occupancy toll (HOT) lanes, in which vehicles with two or more occupants (high-occupancy vehicles) are subject to tolls to drive in special lanes. Variable rates may also be charged, depending

on time of day, for instance. As well, information and communications technologies facilitate the collection of use data and billing (electronic toll collection).

However, coordination among different levels of government is not always successful. In 2008, New York Mayor Michael Bloomberg failed to gain state approval for a congestion pricing plan in the city that would have funded public transit infrastructure.

In Canada, the federal government allocates a portion of gas tax revenues to cities. Although not geared specifically toward transportation expenses, the fund is meant to be directed to municipal infrastructure projects. Municipalities receive funds based on their population.

Governance arrangements have also emerged as a means of developing plans and funding strategies across municipal boundaries. In Canada, the Ontario provincial government has created a regional transportation authority responsible for planning and administering roadway and transit projects in the Greater Toronto and Hamilton Area, in conjunction with individual municipalities. In the province of British Columbia, the TransLink authority was renamed the South Coast British Columbia Transportation Authority and is now governed in part by mayors from all member municipalities of metropolitan Vancouver.

Other Approaches

Planners, researchers, and policy makers also emphasize the role of public transit in alleviating traffic congestion. Funding, however, remains a concern, given long-standing retrenchment in public spending and what some observers consider to be relatively high user fees that on their own cannot sustain a transit system's operating costs. In Toronto, debates over municipal and regional transit funding have seen opposition from local councilors who consider streetcars and light rapid transit vehicles as contributors to congestion.

A number of technical and technological tools have also emerged to predict, manage, and reduce traffic congestion. Transportation or travel demand management makes use of data to develop more efficient uses of transportation systems and provide alternative routes or modes. It may also incorporate education campaigns, incentives, or disincentives to shift commute times and modes of transportation. Similarly, intelligent transportation systems

incorporate advanced technologies to support transportation decision making and management. Active traffic management addresses traffic congestion specifically, relying on real-time data collection.

Driver education has also been cited as an important factor in mitigating traffic congestion (by reducing accidents and aggressive driving habits). Researchers from the University of California, Berkeley and the Massachusetts Institute of Technology have combined data generated through technologies such as the Global Positioning System and smartphone applications to establish relationships between driving habits and traffic congestion. Greater understanding of driving conditions on specific roadways can lead to more regionally based responses, spreading out traffic flows to avoid concentrating traffic in particularly difficult areas.

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See Also: Automobile Culture; Congestion Mitigation and Air Quality Program; High Occupancy Toll Lanes; Road Pricing Schemes, U.S. and International; Smart Growth; Traffic Demand Management; Traffic Flow; Traffic Studies and Surveys.

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Traffic Control Devices

Traffic control devices (TCDs) are the familiar signs, marking, signals, and other devices located along a roadway that provide the primary means of communicating vital information to road users. TCDs use colors, shapes, symbols, words, sounds, and/or tactile information to communicate regulatory, warning, or guidance messages to road users on roadways and other type of facilities that serve vehicles, pedestrians, and bicycles. The messages provided by TCDs help the users of those facilities navigate the transportation network in a safe and efficient manner and provide for orderly movement.

TCDs have been a part of the surface transportation network from the earliest part of the automobile age. From their inception to the 1930s, these devices assumed a wide variety of appearances. In the late 1920s and early 1930s, state highway departments in the United States began working together to create a system of consistent, or uniform, traffic control devices that has been continually improved over the years.

The TCDs in use today provide a coordinated and effective means of communicating information to road users and promoting the safety and efficiency of the surface transportation system. Each country establishes its own practices regarding TCD characteristics. This article focuses upon the system of TCDs used in the United States.

The evolution of TCDs from an individualized design and selection process to a high-level uniform system occurred over many decades through the application of scientific principles, research, engineering experience, and policy-making actions. Today, decisions regarding the various aspects of TCDs are generally made by the governmental agency or private property owner having jurisdiction over the roadway, and these decisions are guided by the national authoritative TCD reference document, which is the *Manual on Uniform Traffic Control Devices*, or MUTCD. In order to appreciate how the MUTCD impacts TCD decision making, it is appropriate to first describe the various activities associated with TCDs and the types of TCDs before describing key aspects of the MUTCD.

Traffic Control Device Activities

While TCDs themselves are physical objects located near a roadway, there are many activities associated

with the process of placing them there. These activities include meaning (definition), design (appearance), selection (use), placement (installation), operation, and maintenance.

The meaning of a TCD defines its purpose, the message it conveys to road users, and the intended user response to the device. TCD meaning can be established through law, regulation, or traffic engineering standards. It is imperative that a TCD have the same meaning no matter where it is used.

The design of a TCD defines its appearance as it appears to road users. Design addresses such features as color, shape, pattern, layout of elements, size of elements, and overall size. In order to establish uniformity in how road users respond to TCDs, design aspects such as color, shape, and layout are standardized so that they appear the same in all situations. Individual design characteristics typically convey specific messages. An example is that red is used to indicate a stop or prohibitory message. A diamond sign shape indicates a warning of a potential hazard.

The selection of TCDs relates to the process of deciding whether it is appropriate to use a given device in a specific situation. The use of a device can range from a requirement at one end to a decision at the other end. The levels of use are identified below.

A TCD is required to be used if specific conditions exist at a location. An example of a required use is that a speed limit sign is required if the speed limit changes on the road. Warrants are criteria that identify minimum conditions that need to exist before a TCD can be considered for use. A device is required to be used if it meets the warranting criteria, but it should not be used if it does not meet the warranting criteria. Warranting criteria may be individual or combinations of factors such as traffic volume, speed, and crash history.

If a TCD meets the warranting criteria, or if there are no warranting criteria, the decision whether to use a TCD at a given location is typically an engineering decision that is made by an engineer (or other appropriately qualified individual). In making such a decision, the engineer considers a variety of factors to decide whether installation of the device will improve safety, efficiency, or other aspects of the roadway.

The placement of a TCD relates to where it is installed in relation to the roadway and the condition to which it is related. Placement criteria are

typically related to the three axes of distance indicated below:

- *Longitudinal*: The distance along the length of the roadway between the device and the condition to which it relates. Some devices are placed at the condition (such as a stop sign) and other devices are placed in advance of a condition (such as a curve warning sign).
- *Lateral*: The distance across the width of the roadway (including the portion beyond the paved road) where the device is placed. The placement can be a location within a particular lane or a distance off the roadway.
- *Height*: The height of a device is its distance above the roadway surface.

Not all TCDs are static and unchanging. For those that have a dynamic appearance, the operation of a TCD describes how the appearance of the device changes with time. The red to green to yellow status of a traffic control signal provides a common example of the operation of a dynamic TCD.

The maintenance of TCDs describes activities related to keeping TCDs performing in the intended manner. TCD maintenance activities include factors such as checking whether a device is missing or has been moved, whether it retains the intended appearance characteristics, and whether it operates as intended.

Types of Traffic Control Devices

The term *traffic control devices* refers to a large number of individual types of devices that can be used on or near a roadway to communicate with road users. The three most common types of TCDs are traffic signs, pavement markings, and traffic signals. Each of these types can be further divided into subtypes as indicated below. There are also less-known types of devices, such as channelizing devices and barricades. This list also describes the purpose of each subtype of TCD.

Traffic signs use words or symbols presented in a vertical plane to convey various types of messages. Regulatory signs inform road users of laws, regulations, or requirements that are in effect at a specific location or over a length of road. Regulatory signs are typically located at the point where the law, regulation, or requirement applies or changes.

Examples include Stop signs, Speed Limit signs, No Right Turn signs, and Keep Right signs. The most common appearance for regulatory signs is a vertically oriented rectangle with a black legend (or copy) on a white background.

Warning signs provide a warning of a potentially hazardous condition that may exist in or near the highway. Warning signs are typically located in advance of a potential hazard. Examples include Curve signs, Stop Ahead signs, and Low Clearance signs. The most common appearance for a warning sign is a diamond with black legend on a yellow background.

Guide signs provide navigational information such as the location of streets and highways, direction of travel, and location of various services. Guide signs can be located at a specific point (such as with a street name sign) or in advance of a specific point (such as an advance freeway guide sign). The most common appearance for guide signs that identify roadway locations is a horizontal rectangle with white legend on a green background. If the sign relates to services, the color combination is a white legend on a blue background. Guide signs related to cultural or recreational locations typically have a white legend on a brown background.

Changeable message signs (CMS) are a special category of sign that can present a message that changes with time. CMS can present regulatory, warning, or guide messages depending upon the needs at a particular location. Permanently installed CMS tend to be used on freeways to inform road users of travel times and road conditions. Portable CMS are used at specific locations for temporary conditions that may need to convey a message that cannot be presented in a static sign.

Pavement markings use patterns, colors, arrows, and words that are presented on the surface of the roadway (on the pavement in a horizontal plane) to regulate, warn, and guide traffic. Longitudinal markings define the location of lanes, the direction of travel within a lane, and restrictions on the ability to change lanes. Longitudinal markings use yellow to separate opposing traffic or define the left edge of the traveled way and white to separate lanes traveling in the same direction or define the right edge of the traveled way. Broken (dashed) longitudinal lines can be crossed while solid lines discourage or prohibit crossing. Examples of longitudinal lines include center lines, lane lines, and edge lines.



A pedestrian LED traffic light in New York City shows an orange hand signal to inform individuals when it is appropriate to enter the intersection. Some of these pedestrian crossing lights also have audible signals to assist those with special needs.

- Transverse markings extend across the roadway to indicate the point where a specific activity should take place. Transverse markings are white and typically use a solid line. Examples include stop lines and crosswalks.
- Word and symbol markings use arrows, words, and symbols to convey a specific message. These markings are typically white. Examples include lane user arrows, words such as ONLY, and the accessibility parking space marking.
- Traffic signals use changing color and shape displays to direct traffic to take a specific action or to provide additional emphasis to a warning message in a sign.
- Traffic control signals assign the right-of-way to conflicting approaches at an intersection. These signals use red, green, and yellow indications to indicate a stop, go, or caution action. Signal indications can be circular or arrow shaped. They can also operate in a steady or flashing mode. Each combination of color, shape, and mode has a specific meaning.
- Pedestrian signals inform pedestrians when it is appropriate to enter and not enter a roadway. The indications are a steady white walking man symbol, a flashing orange hand symbol, and steady orange hand signal.
- Lane-use control signals are placed over a lane to indicate whether the lane is open to travel in the direction from which the signal is visible. Displays include a down green arrow (okay to use lane), a yellow X (prepare to vacate lane), and a red X (lane is closed). Lane-use control signals can also be used to indicate that a lane is used only for left turn movements.
- Intersection beacons use flashing red or yellow circular displays to inform traffic approaching an intersection whether the vehicle must stop (flashing red) or proceed with caution (flashing yellow).
- Flashing beacons use flashing red or yellow circular indications in combination with a regulatory or warning sign to provide additional emphasis for the stop, speed limit, or warning message conveyed by the sign.

Manual on Uniform Traffic Control Devices

In the United States, the use of TCDs is regulated by the MUTCD. The U.S. Code of Federal Regulations (CFR) defines the MUTCD as the national standard for all TCDs installed on any street, highway, or bicycle trail open to public travel. Federal regulations require each state to adopt the national MUTCD or a state version of the MUTCD that complies with the national version (defined as substantial conformance).

While individual state laws vary in the language used, they generally require all TCDs within that state to comply with the MUTCD. Historically, the TCD principles presented in the MUTCD applied only to roads owned by governmental agencies but recent changes in the CFR and MUTCD have extended the application of the MUTCD to private property, as well.

The fact that the MUTCD is defined in federal regulations as a national standard makes it a legal document, and, in fact, it is the only major transportation engineering reference document that is so defined as a national standard. Failure to comply with MUTCD provisions is often a factor in tort liability lawsuits. In fact, a desire to reduce

tort liability exposure is often a motivating factor in complying with the MUTCD, because there is no other enforcement mechanism associated with MUTCD principles.

A concern over the potential of tort liability exposure is only a small factor in the desire to comply with the MUTCD. The TCD principles contained in the document are based on decades of experience in using TCDs and also based on scientific principles such as human factors (such as visibility and perception-reaction time), driver understanding, safety impacts, and operational efficiency. By using engineering experience combined with the MUTCD provisions, those responsible for roadways are working to promote safe and efficient movement of roadway users.

To use the MUTCD, a traffic engineer (or other appropriately qualified individual) must understand not only the legal status of the document but also how the organization and presentation of TCD principles establish different levels of mandate on their use. Users also need to understand how they can use their experiences with TCD effectiveness to impact the continued improvement of the MUTCD.

MUTCD Organization and Content

The 2009 MUTCD is divided into nine parts and each part is subdivided into chapters. Each section address specific devices. Parts 2 through 4 describe aspects of the three basic type of devices. Parts 5 through 9 describe how the three basic types of devices are used in specific types of applications. The stovepipe nature of MUTCD content corresponds with how the document is organized and how content in one part of the manual relates to content in other parts.

Within each MUTCD part, the text is categorized by a heading that indicates the level of mandate (requirement for use) associated with that text. Most of these categories have a specific action verb that also defines the level of mandate, and that has an established legal meaning. The categories and action words are listed below. One of the impacts of this structure is that the headings break up the flow of the information and can make it more difficult to read.

- *Standard*: A required, mandatory, or specifically prohibited practice. The verb *shall* is used in a standard statement

- *Guidance*: A recommended, but not mandatory, practice that is appropriate for typical conditions. Deviations are permitted when an engineering decision indicates such a deviation to be appropriate. The verb *should* is used in a guidance statement
- *Option*: A permissive practice that is allowed, but carries no mandatory or recommended implication. An option may modify a standard or guidance statement. The verb *may* is used in an option statement
- *Support*: An informational statement that provides only background information. Support statements do not establish any mandatory, recommended, or optional practice. Option statements cannot use the verbs *shall*, *should*, or *may*

MUTCD Ownership and Revision Process

The MUTCD is owned and administered by the Federal Highway Administration (FHWA), which is part of the U.S. Department of Transportation. Because it is defined as a federal regulation, changes to the document must be made using the federal rulemaking process.

Ideas for changes to the MUTCD are sometimes developed within FHWA, but are often recommended to the FHWA by the National Committee on Uniform Traffic Control Devices (NCUTCD), which is a private organization whose sole purpose is to develop MUTCD recommendations for FHWA consideration. The NCUTCD is sponsored by 20 organizations that represent a broad spectrum of transportation agencies directly responsible for TCDs and sponsors from other segments of the transportation profession. The typical steps involved in revising the MUTCD are listed below:

- A proposed change or changes to the MUTCD are developed by the FHWA, NCUTCD, or others.
- The proposed change(s) is published in the *Federal Register* and the public is provided an opportunity to comment on the merits of the proposed change(s). For the proposed changes that became the 2009 MUTCD, there were over 1,800 letters submitted to the comment docket and these

letters contained over 15,000 individual comments about the proposed changes.

- The FHWA evaluates the comments and identifies adjustments that should be made to the proposed changes.
- The FHWA publishes a final rule in the *Federal Register* that summarizes the public comments on the change(s) and describes the final decision on the proposed change(s). The final rule becomes effective 30 days after publication in the *Federal Register*.

States have several options for using the MUTCD within an individual state. Most states adopt the national MUTCD as the only TCD manual. Some states adopt the national MUTCD but also issue a state MUTCD supplement. A few states develop their own MUTCD.

The CFR requires that a state MUTCD or supplement be in substantial conformance with the national MUTCD. A state has up to two years to adopt any changes that are made to the national MUTCD, although in some of the states that use the national MUTCD, changes are automatically adopted at the time they become effective. Some states have TCD practices that vary from the national MUTCD and these are allowed to continue if they were established in state law before 2006. The yellow crosswalks that are used in California in school zones are examples of such a deviation.

Future of Traffic Control Devices

The TCDs that are in use today are largely the same as those that have been in use for over 40 years. Recent improvements in TCDs include advancements in controller technologies for traffic signals, use of light emitting diodes in signs and signals, improved retro-reflective materials, and other improvements.

One area of recent improvement that is not a TCD but that affects TCD use is the widespread use of in-vehicle navigation devices. These in-vehicle devices have reduced road user reliance on guide signs and may serve as a precursor to a future where in-vehicle messages may reduce the need for TCDs on some types of high-volume facilities such as freeways. However, traditional TCDs are expected to continue in service for the foreseeable future, although their performance and/or effectiveness may be improved through direct communication between vehicles and

TCDs, improved nighttime visibility, better management of pavement space to adjust movements by time of day, and active warnings of intermittent hazards.

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See Also: Automated Traffic Enforcement; Highway and Road Safety; Road Signage; Road Surface Marking and Markers; Traffic Calming; Traffic Laws and Enforcement; Traffic Signal Priority; Traffic Signals.

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Traffic Demand Management

Traffic demand management (TDM), otherwise known as transport demand management or mobility management (especially in Europe), is a term that refers to a range of actions (for example, policies, programs, and projects) that modify the demand

for transport infrastructure and services in either space or time in order to improve the efficiency of the transport system. The term is distinguished by actions that respond to increases in the demand for transport by adding to transport infrastructure or capacity (that is, supply management), such as extending roads, expanding airports, or increasing space for parking facilities.

The origins of TDM can be traced back to the 1970s when the oil crises of 1973 and 1979 prompted various attempts in the United States to increase the fuel efficiency of transport and reduce oil dependence. TDM was also seen as a way of addressing other economic and environmental policy issues of the time, such as reducing traffic congestion (and thereby helping increase economic productivity) and improving air quality, which had become increasingly important in the United States since the 1960s.

In the 1980s, TDM gained prominence because it was seen as a cheaper and more effective way of dealing with increases in motorization than building additional transport infrastructure. The expansion of existing transport infrastructure, especially in urban areas, was facing increasing difficulties due to the high price and limited availability of land for new infrastructure, the financial constraints of public authorities responsible for providing the infrastructure, and the additional “external costs” on society and the environment associated with the provision of new infrastructure (for example, noise, health, air pollution, and severed communities).

Interest in TDM continued to grow in the 1990s, particularly in Europe, when the underlying philosophy of transport and infrastructure policy experienced shifts in many countries, moving from a predominantly supply-based “predict and provide” approach toward a new realism in which there was greater recognition that, even if new infrastructure is built to accommodate the expected increases in transport demand, levels of traffic, congestion, and pollution can still worsen because there is a substantial latent demand for transport.

TDM encompasses a wide range of measures to influence whether, how, when, where, and how often people travel. TDM measures are mostly related to urban passenger travel rather than intercity travel or freight transport, although the concept is also applicable to these policy areas. Although building additional transport infrastructure or capacity

can technically be categorized as supply management rather than demand management, increasing the capacity of public transport infrastructure or infrastructure for “green” modes (for example, walking and cycling) is generally considered to be a form of TDM.

Benefits

As well as promoting efficiency in the transport system, a variety of claims are made about the wider social, economic, and environmental benefits of TDM, such as that it accomplishes the following:

- Promotes transport choice, particularly for nondrivers
- Reduces the environmental impacts of transport
- Increases the energy efficiency of transport
- Improves the efficiency of land use
- Reduces public spending demands for transport
- Improves public health by increasing walking and cycling
- Reduces congestion, thereby increasing economic productivity

There are various ways of categorizing the main types of TDM measures. The grouping of TDM measures that follows represents just one example of these categorizations.

Education, promotion, and outreach measures can be used to raise awareness, improve understanding, and build positive attitudes about alternative transport choices. Examples include personalized travel assistance, cycle training and education campaigns to promote specific transport modes, and promotion events for public transport or green modes (for example, car-free day, cycle-to-work week).

Regulatory measures can be used to influence the relative accessibility of different modes of transport. They can be employed either to increase the accessibility of certain types (for example, bus lanes, bus-only access restrictions, and high occupancy vehicle lanes) or to decrease the accessibility of other modes (for example, access restrictions for cars). These measures can be applied either indefinitely or just at certain times of the day, week, or year.

Economic measures can be used to make particular transport choices more financially attractive

than others. A range of different measures, both push and pull measures (that is, disincentives and incentives, respectively), are available for this purpose. Examples include fuel taxes, road user charges, parking charges, tax incentives (for example, for commuting by public transport), and subsidies (for example, bicycle purchase subsidies for employees).

Land use measures can be used to influence the density, diversity, or design of urban development, all of which are important in shaping local levels of accessibility and, as a consequence, can influence travel distance and modal choice. Specific examples of land use measures include street layout patterns (which influence an area's permeability for different modes of transport), park-and-ride facilities (which provide an alternative to car journeys), and car parking location and capacity (which influence the number of vehicles with access to an area).

Traveler information measures provide travelers with information about how to reach their destination by different modes (and combinations of modes), the travel time involved, the costs, and sometimes the environmental impacts of these options (for example, energy consumption or CO₂ emissions). These measures can also be linked to real-time travel information to provide travelers with suggestions for alternative routes, modes, or travel times in order to avoid congestion, road closures, or tolls. These measures include online trip planning, real-time roadside travel displays, and traffic condition information.

Information and communication technology measures includes a range of electronic applications (mainly Internet-based) that allow communication or transactions to take place remotely, which reduces or eliminates the need to travel. Examples include teleworking, Internet banking, videoconferencing, and e-government. There are ongoing debates about whether some of these measures (for example, teleworking or videoconferencing) really do lead to less travel or in fact actually increase the overall demand for travel.

Modal integration measures provide ways to reduce the barriers (both physical and economic) to multimodal journeys (that is, journeys involving combinations of modes or transport operators) in order to provide viable alternative options to car journeys. Examples include public transport tickets,

coordinated public transport timetables (using different operators and different modes, such as rail, bus, tram, and ferry), bicycle carrying facilities on public transport, and multimodal travel planning tools (for example, online trip planning).

Organizational measures include measures to create or support organizations, organizational structures, or organizational procedures that promote more efficient transport operation. One commonly encountered example is car sharing or carpooling, which provide a way to increase the occupancy of vehicles and fuel efficiency per passenger.

TDM measures can be applied at the national, regional, or local administrative level. In addition, TDM measures can be site specific. In the latter case, TDM measures focus on managing travel demand at a certain location (for example, an office development, school, concert venue, sports arena, or hospital). In some countries (for example, Germany, Ireland, Sweden, and the UK), approval of planning permission for certain types of development is contingent on preparing a mobility plan that often contains a package of TDM measures.

While there is clear awareness among the majority of travelers about the environmental impact of their actions, their willingness to change behavior is often low because of a mixture of individual and social interests. A well-integrated set of TDM measures is needed to encourage these behavioral changes.

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See Also: Carpool Programs, Ridesharing and; Derived Demand; Green Transportation; Latent Travel Demand; Traffic Congestion; Transportation Control Measures.

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Traffic Detection Systems

Various vehicle detection systems are used to sense local traffic at a particular defined location, to gather and analyze aggregate data for that location, and to engineer or control traffic in that location. Intrusive detectors must be embedded within the roadway while nonintrusive detectors are placed adjacent to or above the roadway.

Researchers, traffic engineers, and policy makers utilize data gathered from vehicle detection systems for a variety of functions. Such data is also a key component in the development of new intelligent transportation systems (ITS) that have arisen to meet the challenge of expanding surface transportation capacity while mitigating cost and environmental effects.

Developed nations such as the United States have large and increasingly congested surface transportation systems. Industrialization, urbanization, suburbanization, the development of interstate highways, and the rise of an automobile culture are key causal factors. Surface transportation demands are expected to continue to increase in the foreseeable future, meaning increased system capacity is essential to traffic engineering, future roadway construction, and congestion reduction programs such as traffic calming.

Technological developments in the fields of telecommunications, computing, and information technology have made revolutionary advances in vehicle detection systems possible while older, time-tested methods with large experiential databases remain in wide usage.

Types of Vehicle Detection Systems

Vehicle detection systems are broadly characterized by whether they rely on sensors that require

placement within the road surface (known as intrusive systems) or do not require roadway embedment (known as nonintrusive systems).

Intrusive vehicle detection systems in use employ a variety of sensor types, including pneumatic road tube, inductive loop, piezoelectric, bending plate, load cell, capacitance mat, weigh-in-motion (WIM), magnetometer, and magnetic sensor systems, while nonintrusive systems in use include microwave radar, passive and active infrared (or laser radar), ultrasonic, passive acoustic array, and video image processors.

Historically, most vehicle detection systems are infrastructure rather than vehicle based. Pneumatic road tubes record the number of vehicles passing a particular location. Inductive loop detectors are one of the oldest and most common of the vehicle detection systems in use. Various shaped loops of insulated wire are embedded within the pavement, creating a magnetic field that detects passing vehicles. Inductive loop systems range from simple to more complex and may collect data in single or multiple lanes of traffic and from vehicles traveling at varying speeds. They provide data such as vehicle counts, vehicle speeds, vehicle length and weight, and distance between vehicles.

Two-axis floodgate magnetometers obtain vehicle data through measuring vertical and horizontal changes in the Earth's magnetic field. They are primarily used in construction zones, bridge decks, and viaducts where loop detectors are not feasible. Magnetic detection systems utilize a wire coil that measures certain changes in the Earth's magnetic field.

Microwave radar uses the transmission of microwave energy, while active infrared uses the transmission of infrared energy. Two common types of microwave radar in use are continuous wave (CW) Doppler radar and frequency modulated continuous wave (FMCW) radar. Passive infrared systems, which do not transmit energy in themselves, rely on the detection of energy transmitted from passing vehicles, the roadway, and other variables to gather data. Ultrasonic systems measure reflected waves from the transmission of ultrasonic sound energy.

Acoustic systems use the passive detection of sound energy or audible sounds to detect vehicles and measure their passage and speed. Video vehicle detection systems employ video cameras installed above or adjacent to roadways. Video image processors digitize and analyze the images to produce

vehicle and traffic data. Uses include traffic flow measurements such as lane occupancy and vehicle speeds and counts, as well as automatic license plate recognition and automatic incident, stopped vehicle, or wrong-way vehicle detection.

The various vehicle detection system types each have their own combination of strengths and weaknesses, which traffic engineers must take into account when choosing which system to install. Lane closures are required for the installation and/or maintenance of certain vehicle detection systems, including inductive loop, magnetometer, active infrared, and video image processors that are mounted above as opposed to alongside roadways.

Many vehicle detection systems can damage roadways or decrease road life span if improperly installed. Inductive loop, active and passive infrared, ultrasonic, and video image processor systems are also themselves vulnerable over time to damage from the passage of traffic and environmental conditions such as temperature extremes. Magnetic and magnetometer-based systems are less vulnerable to traffic stresses in the long term. Systems such as microwave radar, active infrared, ultrasonic, video image processors, and some models of acoustic arrays can provide data for multiple rather than single lanes of traffic.

Different types of vehicle detection systems have varying degrees of accuracy, may require the installation of multiple detectors in certain locations, and may have difficulty detecting stopped vehicles, stop-and-go traffic in heavily congested areas, or large numbers of vehicle classifications. Conditions such as vehicle shadows, extreme weather, fog or wind, dirt, and the transition between day and night can impact video camera lenses. Those less sensitive to inclement weather include inductive loop, magnetometer, magnetic, microwave radar, and acoustic.

Vehicle Detection Systems Data

Selection of vehicle detection system type, placement of vehicle detectors, and resulting traffic controller settings, such as traffic-signal timing, are determined both by analysis and the judgment of traffic engineers based on roadway or intersection type and by whether there is a high- or low-speed vehicle approach. Vehicle detectors are strategically placed along the roadway or other area to be measured, usually within the determined center of traffic flow. Various types of vehicle detection systems are

used either as single systems or as integrated systems combining several types of detection technology.

Vehicle detection systems gather data on such basic traffic variables as presence, speed, headway, gap, vehicle classification, weigh-in-motion (WIM), volume, and occupancy (measured as the percentage of time the vehicle is stationed over the detector). The latter two are the most commonly measured and used variables in the field of traffic engineering. Traffic engineers use the data obtained from vehicle detection systems to design traffic control and calming measures, such as traffic signal control. Data is also used to provide traveler information services.

Traffic engineers introduced ITS in the late 20th century to increase transportation system capacity without widening existing roadways or building additional roadways. The United States adopted its federal ITS program in 1991 under the auspices of the Intermodal Surface Transportation Efficiency Act. An enhanced emphasis on transportation security in the wake of terrorist attacks targeting transportation modes such as aircraft and mass transit has also heightened interest in ITS. Vehicle detection systems are an important component of ITS development because they are one of the primary data collection methods in use by ITS.

ITS relies on a combination of both infrastructure- and vehicle-based vehicle detection systems to gather traffic data. Traffic data obtained through vehicle detection systems aid in the reduction of traffic congestion, improvement of public safety, greater public access to traffic information, cost efficiency of transportation systems, and environmental impact mitigation. New technological developments such as microchip, wireless communications devices such as Bluetooth, RFID (radio frequency identification), and intelligent beacon sensing promise to continue to improve vehicle detection systems and their application to ITS.

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See Also: Intelligent Transportation Systems; Traffic Detection Technology; Traffic Information and Control Systems.

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Traffic Detection Technology

The U.S. surface transportation system consists of millions of miles of roadways that support trillions of passenger and freight miles each year. With transportation volumes increasingly rising, more capacity demands are being placed on the transportation infrastructure and systems in the United States. One approach to accommodate the growing capacity needs is to add infrastructure in the form of new roadway miles. An alternative solution has been to expand capacity through efficiency improvements throughout the existing transportation system.

The efficiency-improvement approach is largely focused on intelligent transportation systems (ITS) technologies that are designed to enhance public safety, reduce traffic congestion, improve access to travel and transit information, generate cost savings for agencies and operators, and reduce environmental impact of transportation activities. The ITS technologies used for traffic detection and surveillance utilize sensor, communication, and traffic control technologies to provide important data on the presence, count, speed, class, gap, headway, occupancy, weight, and link travel time of vehicles. The data is used to help optimize traffic planning, design, control, and management.

Primary Types of Traffic Detectors

Traffic detection systems rely on their ability to sense traffic, which is accomplished through the

use of one or more detector types. The two main types of traffic detectors are known as pavement-invasive detectors, which include inductive loop, magnetometer, and magnetic detectors, and non-pavement-invasive detectors based on microwave radar, active or passive infrared, ultrasonic, acoustic, or video image processor technologies.

Pavement-invasive detectors refer to devices that are installed directly onto the pavement surface, into grooves or holes cut into the road surface, under the surface of a roadway by means of tunneling, or anchored directly onto the pavement surface.

Non-pavement-invasive detectors encompass above-ground sensors that are mounted above traffic lanes or on the side of roadways to monitor multiple lanes of traffic at numerous angles. Like subsurface sensors, the above-ground devices are used to measure vehicle count, presence, and passage, but they have the added benefit of also being able to provide information about vehicle speed, vehicle classification, and multilane traffic volume and flow.

Pavement-invasive detectors. The most common traffic detection technology is inductive loop. It consists of one or more turns of insulated loop wire wound in a shallow slot carved into the road surface pavement. Loop detectors come in a multitude of shapes and sizes. Various configurations can be used based on the area under surveillance, the types of vehicles to be detected, and the objective of the data collection, such as counting vehicles or measuring speed. Inductive loop detectors are insensitive to most inclement weather conditions and have a high degree of accuracy, especially regarding vehicle count and occupancy measurement. However, inductive loop installations are subject to temperature and traffic stresses and often require multiple detectors to effectively monitor a specific location.

Another popular pavement-invasive detector type is a magnetometer. These types of detection devices measure changes in both the latitudinal and longitudinal components of the Earth's magnetic field. Magnetometers are especially useful for assessment on bridge decks and viaducts, where the underlying steel support structures tend to interfere with loop detectors and can be weakened by the embedded loop wire. Magnetometers also are appropriate for traffic detection related to temporary installations in construction zones. Like inductive loop installations, however, magnetometers

are susceptible to temperature and traffic stresses and may require multiple installations to effectively monitor a location.

Magnetic detectors are made up of a coil of wire with an extremely permeable core, a technology that helps measure changes in the lines of flux of the Earth's magnetic field. Since this type of detector can only sense vehicles that are moving faster than a specified minimum speed, they are not appropriate for detecting vehicle presence. However, magnetic traffic detectors are useful in situations where the road surface cannot be compromised or where deteriorated pavement or frost activity has resulted in breakage of inductive loop wires.

Pneumatic road tube sensors deliver a pulse of air pressure through a rubber tube when a vehicle's tires pass over the tube. The burst of air pressure closes an air switch, producing an electrical signal that is transmitted to a software program that analyzes vehicle count data. This type of detection device is installed perpendicular to the flow of traffic to provide short-term traffic counts, including vehicle classification by axle count and information about vehicle spacing. Some models calculate vehicle gaps, intersection stop delay, stop sign delay, saturation flow rate, spot speed as a function of vehicle class, and travel time when the counter is utilized in conjunction with a vehicle transmission sensor. Pneumatic road tube sensors are quick to install and are typically low cost and simple to maintain. The tube sensors are subject to wear, weather, and high-volume inaccuracy of axle counts.

Piezoelectric sensors are another type of pavement-invasive detection technology. Piezoelectric is a specially processed material that converts kinetic energy to electrical energy. Piezoelectric sensors are constructed using a coaxial with a metal, braided core element, and piezoelectric material surrounded by a metal outer layer. During the manufacturing process, the sensor is subjected to an intense electrical field that polarizes the piezoelectric material.

The material is used to generate voltage when subjected to mechanical impact or vibration that is proportional to the force or weight of the passing vehicle. Piezoelectric sensors are used to classify vehicles by axle count and spacing and, when multiple sensors are activated, to measure vehicle weight and speed. These types of sensors are commonly used as part of weigh-in-motion (WIM) systems (see below). They are unique in that they

gather information on vehicle tires passing over the sensor instead of on the passing of a vehicle, providing highly accurate differentiation of individual vehicles for precise counting. Once installed, the cost of piezoelectric sensors is only slightly higher than inductive loops, but they offer more information regarding vehicle speed, classification, and weight. Disadvantages include failure due to poor road surfaces or vandalism and sensitivity to pavement temperature and vehicle speeds.

WIM systems are used to estimate the gross vehicle weight of a vehicle, down to the proportion of weight carried by each wheel assembly, axle, and axle group. The information is used for highway planning, design, and safety enforcement. Specifically, WIM systems provide highway planners and designers with time and date of traffic volume, speed, vehicle classification based on number and spacing of axles, and the equivalent single-axle loading that heavy vehicles place on pavements and bridges.

The heavy-truck axle load data are used by motor vehicle enforcement agencies to plan enforcement activities. Accuracy of WIM systems is based on vehicle dynamics, such as suspension and driver activity; pavement composition and integrity, including surface texture and condition anomalies; and inherent system variances due to calibration and technology functions.

Non-pavement-invasive detectors. Microwave radar technology is not pavement invasive. It detects traffic presence, flow, and speed by transmitting microwave energy toward the roadway. Frequency modulated continuous wave radar is used to detect vehicle presence, while continuous wave Doppler radar detects vehicle flow and speed. It can be used for multiple-lane operation and is largely insensitive to inclement weather. Some radar-based detection systems are hindered by steel structures found in some large bridges.

Infrared detection is a widely used approach to traffic surveillance for data collection. Active infrared technology transmits infrared energy from a detector and measures the waves that are reflected back. By transmitting beams, active infrared technology provides for accurate measurement of vehicle position, speed, and class. Passive infrared technology does not actively transmit energy but detects energy from vehicles, roadways, and other objects as well as energy from the sun reflected off those

materials to provide an accurate measurement of vehicle speed. Detection devices that use infrared technology are more sensitive to weather conditions and require periodic maintenance, such as lens cleaning, that necessitates temporary lane closure.

Ultrasonic detectors transmit ultrasonic sound energy waves. They measure the distance that the reflected wave travels to determine vehicle presence, count, and lane occupancy. Ultrasonic devices can detect across multiple lanes of operation and are capable of detecting over-height vehicles, but large pulse repetitions may degrade occupancy measurement of moderate-speed vehicles on freeways.

Acoustic technology is used to measure the presence, passage, and speed of vehicles through passive detection of acoustic energy, or sounds created by vehicle traffic. It is largely impervious to the effects of precipitation and can operate across multiple lanes. On the negative side, cold temperatures and significant background noise may reduce vehicle count accuracy from acoustic detection sensors.

Video image processors use video cameras to detect traffic. The resulting images typically are digitized and converted into a broad array of traffic data. The main advantage of video detection is that it can measure traffic over a wider geographic area by linking information from multiple cameras at different locations, as compared to measurement at a single point provided by inductive loop sensors and other pavement-invasive detectors. On the other hand, the performance of video image processors can be affected by weather conditions and camera motion, and they involve more difficult installation and ongoing maintenance.

Cost Considerations

The total cost involved in using traffic detection technologies varies widely, based not only on the type of device but also on the time and expense needed for initial installation, ongoing maintenance and repair, and appropriateness for meeting the data collection needs of the transportation system.

Installation costs for inductive loops, for example, should be calculated to include expenses needed for technicians to prepare the road surface before embedding the sensors. Similarly, the costs for installing infrared sensors should take into account the expenses tied to preparing the structure on which the sensor will be mounted. In addition, there

may be costs tied to traffic lane closures required for traffic detection system installation.

Total costs for traffic detection systems also depend on the frequency and intricacy of ongoing maintenance and life cycle repairs. Less expensive devices may end up being less cost effective in the long run if they require repeated attention or replacement compared with devices that may be more expensive up-front but offer cost benefits in the long term from a reduced need to fix or replace.

The number of traffic detection devices needed to meet surveillance and data requirements also comes into play when determining total costs. For example, numerous inductive loops are needed to cover a multilane, multizone area that could be covered with just one video image processor.

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See Also: Emerging Technologies; Traffic Detection Systems; Traffic Flow; Traffic Monitoring; Traffic Studies and Surveys; Vehicle Miles Traveled.

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Traffic Engineering

A branch of civil engineering, traffic engineering uses the techniques of engineering to plan transportation features that result in well-managed traffic flow. Civil engineering is the parent of most non-military engineering disciplines and is concerned with design and construction, especially of public works and infrastructure. The concerns of traffic engineering overlap with other types of

civil engineering, particularly highway engineering, transport engineering, and pavement engineering. While other engineers engaged in the process are responsible for planning the infrastructure of a transportation system, such as a bridge or a new road, traffic engineers plan the traffic control and management devices and features of that system.

For instance, a traffic engineer's area of concern would include the traffic signals and signs on a transportation route, and possibly modifications to speed limits, as well as traffic control measures such as speed bumps, traffic lights, road surface markers and lane markers, sidewalks, crosswalks, bicycle lanes, high-occupancy vehicle (HOV) lanes, and other features.

There is an element of traffic forecasting in the traffic engineer's job. Traffic engineers are involved with the planning of new transportation projects because their expertise allows them to estimate the traffic impacts of proposed changes, such as the effect on traffic through adjacent neighborhoods and streets of a new outlet mall, or the amount of traffic a bridge can be expected to see in a given amount of time and what that says about the proposed time frame of scheduled repairs or preventive maintenance work. Traffic engineers also present estimates about short-term impacts on traffic (for example, from construction, road closures, flooding and other weather impacts, or special events resulting in increased traffic flow) and propose solutions (for example, detours, reroutings, lane closures, and plans for pedestrian traffic).

They may also make recommendations about traffic control during accidents or brief construction (such as utility work, in which the work site continually moves over the course of the day, rather than blocking off a specific spot for a longer period of time), and what sort of traffic control methods (for example, an on-site traffic controller, flagger, or police officer, or mobile signs and other equipment) should be used. Construction traffic control is sometimes outsourced to dedicated companies, the larger of which may engage the services of a traffic engineer for consultation.

Traffic engineers may also consult with urban planners and state and municipal leadership in preparing evacuation routes in cities prone to natural disasters, making them necessary, such as in the hurricane-prone parts of the country. The New Orleans evacuation route, for instance, must take



Traffic engineering projects like this complex intersection may make use of findings on high crash rate locations and countermeasures to reduce crashes. Traffic engineers often work in conjunction with computer and electrical engineers.

into consideration the limited number of routes out of the city (which is surrounded by water) and the possibility of street flooding in the lower-lying areas. The increased use of computers and sophistication of specialized software have amplified the role of civil engineers in urban planning, because computers can handle the data and calculations necessary to forecast the possible results of various options.

Modern transportation systems increasingly provide the opportunity to supply traffic engineers with data for their work. Sensors provide better and more accurate traffic flow information than was available in the past, including not only the number of cars using a route but their average speed, the frequency of lane changes, and changes to traffic flow over the course of the day. Sometimes traffic flow information can be cross-checked against accident statistics in order to make suggestions to improve safety.

Dynamic elements can also be incorporated into road infrastructure, such as electronic traffic signs that can warn drivers of congestion or accidents. In some municipalities, dynamic lanes are used, changing the directionality of a lane of the street according to the time of day in order to respond to

traffic flow (typically following commuting patterns so that more lanes lead workward in the morning and homeward in the evening).

Some traffic engineers are employed as safety engineers, incorporating not only traffic information into their work but driver psychology. These engineers collect traffic and accident information to look for patterns, and identify areas or times in which accidents are disproportionately common, or about which driver complaints have been registered. The engineer's safety recommendation report will include both possible solutions (and an analysis of the cause, if it was not previously known) and cost-benefit analyses, as well as an analysis of the possibility that the solution will merely "squeeze" the problem elsewhere. Another problem traffic engineers seek to prevent is severe or recurring traffic jams or gridlock. It is assumed that, in some cases, this is unpreventable, but congestion can be managed, and the position of lanes, on-ramps, and exits can help limit the effects of congestion.

Traffic engineers working for transit companies help determine the potential or probable ridership of a route and plan the best locations for bus or train stops, as conditions permit. They can also help estimate bus dwell time—the time spent at any given stop, as a result of passengers embarking or disembarking—and the effects of traffic congestion and other traffic conditions on route scheduling.

Traffic engineering overlaps with transport engineering, which plans and designs transportation facilities for the transportation of passengers and goods, including the subdisciplines of aerospace engineering; air transportation engineering; highway engineering; pipeline engineering; waterway, port, coastal, and ocean engineering; and urban transportation engineering.

Both traffic and transport engineering are critical to urban planning and necessitate an awareness of political factors that impact the work at hand. They also both rely on an urban transportation forecasting model to forecast transportation use and traffic effects, based on what can be known or estimated about automobile ownership, land use, mode choice, route assignment, trip generation, and trip distribution.

While transport engineering is tasked with the design and construction of a highway, traffic engineering determines the capacity it will need.

Traffic engineers also assist in the planning of new major airports, in determining their best placement, the best way to adjust the highway system to accommodate them, and the effects on traffic patterns not only of passenger cars but of any bus routes and taxis.

Traffic engineering plays a role in pavement engineering, which is concerned with constructing asphalt and concrete pavements and their use in streets. Accurate traffic data tells a pavement engineer the type and amount of use a given paved surface can be expected to experience and how often repairs are likely to be needed, as well as which times of day repairs can be scheduled in order to reduce their impact on traffic flow.

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See Also: Highway Planning; Highway/Road Capacity; Institute of Traffic Engineers; Traffic Forecasts.

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Traffic Flow

Conventionally, traffic flow is considered to be the movement of motor vehicles along roads. The theory and principles developed for this can, however, be used for the movement of any discrete autonomous units along a road that are not subject to external time-tabling or control (for example, walking between and within terminals at an airport, cyclists on bikeways, etc.). For the purpose of this article, only motor vehicles on roads are considered. The impact of different kinds of vehicles on different roads is also discussed.

Analogies

In certain circumstances, traffic flow has similar characteristics to fluid dynamics. This is especially true for freeways, where the majority of vehicles are passenger cars with similar dynamic characteristics. Freeways are also designed to provide the smooth access and exit of motor vehicles from traffic streams. On freeways, there can be streamlined flows when traffic volumes are under road capacity and traffic is moving at nearly constant speed. As in fluid dynamics of liquids in a pipe, the traffic nearest the side flows more slowly than the traffic in the center of the road.

Turbulent flows occur when traffic volumes approach road capacity. This leads to shock waves caused by minor disturbances, such as a vehicle stopping on the road edge. At traffic volumes close to road capacity, such disturbances cause traffic to come to a halt randomly; it then starts again flowing freely, until it comes to another halt.

For all other roads, with mixed traffic mixed use (for example, roadside parking, bus stops, and others), traffic flow is more like Brownian motion—random and difficult to model, except at a macro scale. Nevertheless, traffic flows on such roads are important because they lead to and away from major roads like freeways. So, there is little point in having a freeway if its feeder and distributor roads are at a standstill. This will cause traffic to back up the freeway and bring it to a halt, with a zero flow.

Measurement and Impacts of Vehicle Types

Historically, traffic flows were measured manually and recorded on paper charts. Two main methods were developed: static roadside and “moving car,” the latter also determining the average traffic flow speed. Today, there are many remote or telemetric methods to capture real-time traffic flows. Some of these methods include magnetic loops in the road surface, which can also be used to determine vehicle speeds; closed-circuit television (CCTV) with vehicle-recognition software; and radar, among others. When coupled with software, not only can traffic volumes be recorded, but also traffic problems predicted, which can be used to trigger automatic control systems or alert traffic control staff.

The biggest impact on traffic flow is the mixture of large- and private-car-sized vehicles. Determining this can help planners and engineers get a better understanding of the mechanics of traffic flow.

This has led to adoption of a standard unit to represent traffic flows, the passenger car unit (pcu). This models the impact on traffic of a single passenger motor car. All other road vehicles can be represented in pcus. So, a rigid bus is 2.5 pcu, an articulated truck 4 pcu, a motor cycle 0.5 pcu, a pedal cycle 0.25 pcu. By this means, a heterogeneous traffic stream can be represented and measured in standardized (pcu) units.

Capacity, Speed, Volume, and Flow Relationship

Capacity is the theoretical ability of a road to carry traffic. A freeway lane can theoretically carry a maximum flow of 1,200 pcu per hour. An urban mixed-use road can carry a maximum of only about 800 pcu per lane per hour. Volume is the actual number of vehicles flowing along the road, which, by definition, is less than the capacity.

Traffic flow speed interrelates with volume. Obviously, if the traffic speed is zero, then the volume is zero, because there is no flow. As traffic speed increases, the volume increases, until it reaches a maximum on freeways at between 30 miles per hour (mph) and 40 mph (50 to 65 kilometers per hour, or km/h). After that, faster traffic flow speeds progressively reduce volume. The reason for this is that braking distances are a square of vehicle speed, so drivers leave progressively longer safe stopping distances between vehicles as traffic speed increases.

Measures to Improve Traffic Flow

Henry Barnes, one of New York’s former traffic commissioners, is reported to have said when visiting London in 1955 that he could sort out the traffic problems with a bucket of white paint and a brush. His point, which is still valid, is that measures to organize and manage traffic flows, in particular to minimize vehicles weaving between lanes, improve both flow and volume. To this end, effective and advanced signage allows drivers to maneuver in good time and smoothly, and therefore avoid creating perturbations in the traffic stream, which can create dangerous shock waves.

On urban roads, one-way streets have a greater traffic capacity than two-way. The reason for this is that traffic in opposite directions takes more space to pass than traffic going in the same direction. Many cities have therefore created complex networks of one-way streets. Often an additional traffic lane can

be created by converting from two-way flow to one-way, such as four lanes into five lanes.

Categorizing roads into “main” and “other” allows parking to be banned on main roads, greatly improving traffic flows, and restricting parking to other roads and off-road sites. The improvement in traffic flow on main roads would then be a result of both the release of parking space for moving traffic and the removal of stopping and reversing (parking) vehicles disturbing the smooth flow of other traffic.

Most cities use traffic signals to control safely the movement of opposing streams of traffic at intersections. Originally, such signals were on a fixed-time regime, usually adjusted to give the main road more time than the side road(s). At times of low volumes, this leads to traffic waiting for a green while there is no traffic crossing. This frustration for drivers was overcome by the use of vehicle-actuated signals. A pneumatic tube across the road is depressed by approaching vehicles, and when enough have arrived, the signal turns green.

This is fine for isolated intersections that are far enough apart not to interfere with each other's traffic flows. For road networks with close intersections, arranging the signals to work in harmony improves traffic flows. One way to do that is to organize groups of vehicles into “platoons” and then treat each platoon as a unit of traffic. By this means, intersection capacity can be increased when the signals are coordinated with platoons in opposing directions crossing in a synchronized manner. This should also lead to every platoon being able to pass successive intersections without stopping, with “green wave” signal coordination.

Pioneering studies on “area traffic control” were undertaken in Glasgow, Scotland, in the 1960s, where the green waves were set using historical traffic flow data. Today, with more powerful computers, the green wave can be adjusted in real time from contemporaneous traffic data, optimizing volumes and minimizing vehicle delays. One of the experiments undertaken in Glasgow was to answer the question how long it took drivers to adjust to different green wave speeds. The answer was about two weeks. Immediately after a green wave speed was changed, traffic flows were turbulent. This turbulence decreased with time and after two weeks, flows were as streamlined as they had been before the change of green wave speed.

Finally, metering traffic onto the critical road network or freeway allows traffic to flow smoothly and delays to be transferred to feeder roads. This metering requires the traffic on the main road to be monitored to identify gaps in traffic flows, allowing traffic on from ramps. When traffic on the main road approaches capacity, before flows become turbulent, traffic from side roads is stopped until the volume on the main road reduces, and free flow conditions are restored.

This metering can also be coordinated with advisory operating speed on the main road. When traffic at 60 mph (95 km/h) approaches the maximum capacity, the advisory speed can be reduced to 50 mph (80 km/h). This increases effective capacity.

Measures to Manage or Restrict Traffic Flow

Most roads do not exist solely for the movement of motor vehicles. Many roads have pedestrians, shops and commercial premises that require the delivery or collection of goods, and parking to visit properties along the road. While one-way traffic networks improve motor vehicle flows, they create problems for other road users, principally pedestrians, who find crossing roads carrying large flows at fast speeds difficult and dangerous.

Traffic also causes environmental problems of air pollution and noise, both of which make working and shopping in the areas near busy roads less attractive. This has led in the last 20 years to cities adopting progressive measures to reduce central business district (CBD) traffic flows, encouraging motorists to use more environmentally friendly modes, such as buses or light rail. Road space can then be reallocated to more environmentally benign uses, such as bike and bus lanes, tree planting, wider sidewalks, and so forth.

There are two main ways in which traffic flows can be reduced. The first is the physical removal of road space. Clearly, this cannot be done as a one-off, because this would be very disruptive. Using small incremental capacity reductions over a number of years, though, allows traffic to adjust to the new conditions easily and smoothly.

The second method does not involve removing road space but removing (short) through routes, requiring through traffic to use more circuitous routes. This was first tried in London in the 1960s (Pimlico Experiment), and researchers found no significant increase in traffic in surrounding roads

from displaced traffic. This is the inverse of the traffic law, which states that volume increases to fill the available space.

Environmental Capacity and Social Acceptance

Some roads have been built specifically to carry motor traffic, such as freeways, and others have evolved into arterial traffic streets, where previous residents have moved away and been replaced by commercial or retail uses. Streets where people live are not suitable for through motor traffic and have a maximum environmental capacity, variously thought to be no more than 200 pcu per hour, from residents' attitude and behavioral surveys.

Such residential roads, where they are also through routes, need to have traffic managed only to accommodate traffic that is accessing premises in the area. There are various methods to achieve this, ranging from road signs to reorganizing traffic movements to physically closing some roads to make through journeys impossible. This was pioneered in the Netherlands with *Woonerfen* ("home zones"). These traffic management measures not only calmed traffic, but traffic laws also gave priority to human-powered modes of travel—walking and cycling.

Motor cars and cities are almost the worst combination for the movement of people with a minimum impact on the environment. Cities where most travel is by car require a large proportion of the land to be given over to roads and parking. Motor traffic creates toxic air pollution, now the single most critical source of such pollution, known to kill many times more people than traffic crashes. Transit, walking, and cycling are more environmentally benign, but motorists with a choice appear to be unwilling to leave their cars at home. On top of this, traffic noise is now the single most intrusive noise nuisance in most cities, making conversations difficult in streets.

Improving Mixed Traffic Flow Safety

Slowing traffic reduces not only environmental impacts but also the consequences of collisions between soft slow-moving and hard fast-moving objects. Pedestrians hit by a car at 40 mph (65 km/h) stand less than 20 percent chance of surviving. At 30 mph (50 km/h), there is a 50 percent chance of surviving, and at 20 mph (30 km/h), there is an 80 percent chance of surviving.

Reducing vehicle speeds in principally residential areas, where most pedestrians are hit, will therefore significantly improve safety, without slowing journeys by very much. A 2-mile (3-km) journey at 20 mph (30 km/h) takes only six minutes, and at 30 mph (50 km/h), four minutes.

Traffic flows are more than the mechanistic movement of motor vehicles. They are fundamentally part of the transport system of a city and also reflect the environmental quality and civic expectations of its citizens.

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See Also: Traffic Calming; Traffic Congestion; Traffic Control Devices; Traffic Engineering; Traffic Management Systems; Traffic Mitigation Programs.

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Traffic Forecasts

Traffic forecasts are estimates of the number of vehicles or people taking a given route or using a given road (or other transportation project, from a specific bridge, to the 3:10 p.m. bus, to the Delta flight from Cleveland to Austin) in a given period of future time, and of the conditions of traffic as a result of that number and other available data. Such forecasts inform transportation planning decisions, and multiple forecasts can be used to choose between various options.

Traffic forecasts are a necessary part of the most basic parts of transportation planning; the decision whether to construct a commuter rail line from a city to a suburb depends on an accurate forecast of how

many residents of that suburb will use it to commute to the city, for instance, and the mapping of school bus routes depends on knowing how many students live along a given proposed route.

Traffic forecasts also impact decisions at higher levels of policy, such as the setting of speed limits, the deployment of highway patrol vehicles, building an expansion of an airport, or picking a location for a new school, park, or playground. They are also necessary components of other analyses, such as environmental impact statements, social impact statements, and the cost-benefit analyses of many transportation and infrastructure projects.

Traffic forecasts may also be prepared for a specific type of scenario rather than a specific period of time, such as forecasting the impact of a road closure, construction project, or weather event. Weather event traffic forecasts are important in developing weather emergency plans for a city or region, because the impact of flooding, fires, hurricanes, or ice and snow on traffic affects evacuation plans and the dispatch and deployment of emergency personnel, as well as other basic city functions.

The geographical area considered by a given traffic forecast or other transportation planning model is called a traffic analysis zone (TAZ). Zones may be of any size, but modern urban planning software usually assumes a zone with a population of less than 3,000. Census information provides population and socioeconomic data, and the specific types of data included in analyses vary from institution to institution, with each state's own Department of Transportation (DOT) typically providing a guidebook detailing which data to include. Usually, the number of automobiles and household income are both included, as they are valuable indicators of transportation usage and mode choice.

Four-Step Process

There are many methods of traffic forecasting and modeling, varying in methodology, sophistication, and appropriateness for different purposes. The classic urban transportation planning system model uses four steps: trip generation, trip distribution, mode choice, and route assignment.

Trip generation is the process of predicting the number of trips transpiring within the TAZ, whether originating or ending there. Depending on the purposes of the forecast, this may be expressed in terms of a number of trips within the period

of time being forecast or in terms of frequency of trips. There are various methods of trip generation. For intercity travel within the United States, the Transportation Systems Analysis Model (TSAM) is the nationwide standard.

Trip distribution is sometimes called destination choice, and it forecasts the end point of each trip. Specifically, it creates a trip matrix, listing the number of trips made within the traffic analysis zone between any two points. The importance of specificity of forecast in trip distribution varies according to the scope and purpose of a traffic forecast. For instance, it is all but irrelevant in the traffic forecast of the level of usage of a particular bridge. The trip distribution may tell you something about the effects of a detour should the bridge be made unavailable, but if the purpose is simply to determine the amount of wear and tear undergone by the bridge and how soon it will need maintenance, then trip distribution has little effect.

Replace the bridge with a highway in this example, though, and trip distribution differentiates cars that travel the highway's entire length from cars that travel for only two exits, which is important information for maintenance, toll revenue, safety and security, and predicting traffic problems. And if the highway were instead a subway system, trip distribution would be critical in understanding the subway's ridership, revenue, and whether passengers will be left behind at certain stops because of overcrowding.

Work on trip distribution models had been fairly primitive until Alan Voorhees's 1956 *General Theory of Traffic Movement*, which introduced a mathematical formula using land use to forecast traffic patterns. Voorhees's work continues to be fundamental in urban planning and the planning of public works, and it was his work that introduced the trip matrix. Subsequent work analyzed various models for accuracy by feeding them data to forecast situations where the results were already known, such as the amount of traffic in a given city in the 1940s.

Key to trip distribution models at the time was the gravity model, which posits a relationship between the increasing distance between two locations (where distance can also represent transit time or cost of transit) and a decreasing interest in passengers traveling between those two locations. The farther from the city you go, the fewer people are commuting home from it, for instance. The

exact rate of decline is dependent on context, but mathematical work in numerous areas continues to confirm the accuracy and usefulness of the gravity model's basic underlying relationship. Later work on trip distribution in the 1980s included methods that performed the trip-distribution and mode-choice stages in combination, and the borrowing of mathematical methods from other fields, such as entropy analysis from statistical mechanics.

Early trip distribution models were unable to model the effect of travel congestion on trip distribution, that is, the possibility that the presence of heavy traffic would alter a traveler's choices, which is clearly an important real-world phenomenon. This effect is sometimes called "travel resistance," while other models simply count it as travel time and are built such that increases to travel time in a given trip segment alter the trip matrix outcome.

One way to think of the effect of travel resistance is to consider a jogger who jogs for a half hour every

morning. Factors such as obstacles that impede his jogging and his own speed will determine the exact trip he makes, based on that half hour. When he first begins his jogging habit, this may be a short half-mile trip, while a year later it may be a two-mile trip, as his endurance has increased. This is a simplified model, because it assumes the existence of a rigid travel time budget that drives choices without the influence of other inputs, whereas real-world situations are more complex.

Mode choice is a hypothetical passenger's choice of transportation mode. Planning a subway system, for instance, requires making assumptions about how many passengers (and, broadly speaking, which passengers along which routes) will choose to use the subway and which will continue to use other modes of transportation, and what factors influence those choices or could cause them to change. (Those who choose pedestrian transportation but have access to subway transportation may



A train at Cleveland Circle on the Green Line "C" Branch of the Massachusetts Bay Transportation Authority subway in Boston, Massachusetts, serves as an excellent example of a mode choice model. Passenger behavior and the choices they make regarding their mode of transportation are important elements of traffic forecasting. A forecast can estimate the number of vehicles on a bridge, the ridership on a railway line or subway, the number of people at an airport, or the number of ships docking at a seaport.

elect subway transportation for weather-related reasons, for instance.)

Increases in automobile ownership can generally be assumed to decrease activity in several modes while increasing activity in driving. This is an area where the study of historical data is especially useful. Forecasting the effect of adding a new subway line can be informed by studying the effect of an earlier subway line, or a subway line in a significantly similar neighborhood in another city.

Mode choice models draw heavily on psychology, because passenger behavior must be modeled based on what passengers perceive rather than on what is true. They also frequently must use nested models. The potential passengers of our aforementioned new subway system are not choosing simply between car and subway, but between car and subway and walking and bicycle and taxi, and within those choices may have other choices to make.

In Boston, for instance, while using the Massachusetts Bay Transportation Authority (MBTA), there are two simple ways to travel from Cleveland Circle to Harvard Square, either taking the 86 bus, which runs infrequently but does not require any transfers and is cheaper than the subway, or taking the Green Line subway most of the way and then transferring to the Red Line. The subway runs more frequently, so, at any given point, the wait time before the trip begins is likely to be shorter if the subway is chosen, but the total amount of time spent in transit once the trip begins is longer and slightly more expensive. Bad weather may make the subway choice more likely, but an important factor is the perceived inconvenience of the need to transfer versus the perceived inconvenience of the longer wait at the bus stop. Another factor impacting choice is that each mode drops the passengers off at a different part of Harvard Square, which may be more or less near their final destination.

Route assignment is the last step of the four-step forecasting model, and consists of the creation of modeled traffic along specific routes. Having determined how many trips will be taken and how those trips will be distributed on the trip matrix, the forecaster then determines which mode of transportation will be used for the trips. The route assignment is the assembly of all this information.

Route assignment is affected both by travel demand—the number of passengers who need to go places—and network supply, which are the

available routes to take them to those places. Demand increases supply. Before a subway route from the city to the suburbs is created, traffic between those points may consist mainly of commuters and special-event attendees (for example, sports fans, concertgoers, convention attendees), but the creation of the route will increase the total amount of traffic from the suburbs to the city, not simply divert the existing bus and car traffic onto a different mode.

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See Also: Gravity Models; Mode Choice Models; Traffic Engineering; Traffic Flow; Trip Distribution Models; Trip Generation Rates and Models; Urban Transportation Modeling System.

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Traffic Impact Assessments

Traffic impact assessments (TIA), also called traffic impact reports, traffic impact analyses, and traffic impact studies, present information on the projected effects on traffic of a planned development, such as a new office building, stadium, shopping center, or residential development, and can also be used to evaluate the effects of a possible transportation project. They are principally quantitative rather than qualitative analyses, and often rely on standardized methodologies and data sources. Since the late 1980s, state agencies have increasingly required traffic impact assessments as part of the development review process, and they have

been part of the process for municipal agencies for much longer than that. TIAs are usually prepared according to specific guidelines required by the relevant state or municipal agency, but may contain information exceeding those required minimums. A number of software packages exist to assist with the traffic impact analysis process.

TIAs may be used by city planners in considering the merits of a proposed transportation project, anticipating effects that may need to be addressed, and comparing the effects of multiple possible solutions to a transportation problem. The scope of the project being examined may be as simple as a new turn lane or as complicated as a new highway or the street layout of a planned community. A traffic impact assessment may also be one component of a larger impact assessment that considers the economic and environmental impacts of a proposed project as well.

New transportation infrastructure and new development always generates new traffic. Depending on the capacity of the transportation infrastructure used by that traffic, this may result in numerous negative effects, including traffic jams, accidents, the environmental effects of air pollution, the social effects of noise pollution, and increased fuel use and travel time. Further, driver behavior may change in ways unintended by the planners. For instance, if new development results in traffic congestion near that development, drivers ordinarily using those roadways as throughways may divert to alternate routes, which may “squeeze” the congestion elsewhere or may direct high-speed traffic to lower-speed-limit roadways. Commuter traffic may wind up rerouting through largely residential neighborhoods unaccustomed to it.

Similarly, new transportation infrastructure will impact not only the traffic patterns of the traffic using the infrastructure itself but the routes drivers use to reach the new infrastructure. A new highway on-ramp may “pull” traffic accustomed to using an on-ramp farther upstream, creating new traffic patterns in the form of the routes they use to reach the new on-ramp, while bleeding that traffic off the routes they had used to reach the existing one. In some cases, of course, this may in fact be the goal: the new on-ramp may be constructed specifically in order to alleviate congestion in an area where population density has risen. In other cases it may be an unforeseen side effect of an

on-ramp built to provide access to a new commercial development.

Traffic impact assessments vary in their complexity and depth in accordance with the project being examined. They are an important part of land use and urban planning. There are standard statistical analysis tools used to predict, based on the available information about existing traffic patterns and traffic patterns in situations similar to the one proposed, information like additional traffic volume, wear and tear on infrastructure and the necessity and cost of future repairs and maintenance, and increases to the likelihood of traffic collisions in problem areas.

Trip Generation Data

One of the basic components of constructing a traffic impact assessment is assembling trip generation data. Trip generation is the number of vehicle trips that are expected to be generated as a result of the project during a specified hypothetical period of time. Sometimes trip generation data will be determined both for an average day and for peak hours, since the latter is crucial information in examining the possibility and effects of congestion. The Institution of Transportation Engineers (ITE) provides a trip generation manual that is the standard source of trip generation data in the United States. For instance, according to the ITE’s manual, each dwelling unit in an apartment building generates 0.41 peak hour trips, while each dwelling unit in a retirement community generates 0.29 peak hour trips, and each employee in an office building generates 0.48 peak hour trips.

When trip generation rates are constructed, they make certain assumptions about pass-by rates, among other factors. A pass-by trip is one in which traffic travels to a particular destination en route to some other destination. These trips are therefore not generated, as such, by the proposed project, because they would have occurred anyway. For instance, convenience stores and fast food restaurants with drive-through windows are assigned high pass-by rates by the ITE (40 percent in both cases) because most drivers arriving at these locations are stopping off (or driving through) as part of some other trip that they would be taking anyway. On the other hand, fine-dining restaurants have a low pass-by rate because most drivers arriving there have taken a trip for the express purpose of dining there and would not have made the trip otherwise.

Obviously, high pass-by rates reduce trip generation numbers. This becomes further complicated when considering trip generation for multiuse developments, which overall reduce trip generation.

In some cases, trip generation may be the only part of a traffic impact assessment that is required, insofar as other elements are required only of projects that will result in more than 100 peak hour trips (the threshold recommended by ITE). In other cases, a traffic impact assessment will be needed regardless of trip generation data, because of other factors. Common factors that result in a traffic impact assessment being required regardless of trip generation include the use of a drive-through window in a proposed commercial development, developments with inadequate sight distance, proposed access roads without left turn lanes, and developments on high traffic roadways.

Elements

A traffic impact assessment typically covers certain basic areas. It begins with a description of the proposed project the impact of which is being assessed and of the traffic area under study. In the case of a development or a new element of infrastructure, this includes specifying the locations of access points, such as the connecting streets to a new road, or the road on which a new development would be located. The peak hours used in the study are identified explicitly in order to make the terms of discussed impacts clear.

In order for the traffic impact assessment to be put in context, a discussion needs to follow of the existing traffic conditions, including not only the relevant transit infrastructure but traffic patterns, intersections, presence or absence of traffic signals, and traffic counts both during peak hours and as daily averages. In general and as applicable, any time a projected traffic statistic is going to be discussed in the assessment, the current and historical analogues to that statistic should be presented for purposes of comparison. For instance, if a new shopping center on a certain road is going to generate a certain number of trips, it needs to be clear how significant that number is based on the traffic the road already experiences.

After thus discussing present traffic conditions, projected trip generation is discussed, with explicit reference to the data and methods used to project it. Tables should show estimated traffic movements,

including direction and volume. In the case of a development, matters like parking and (in applicable climates) snow plowing must also be addressed. Depending on the project being examined, it may also make sense to discuss pedestrian and bicycle traffic, or the projected access and use by trucks.

Finally, recommendations may be made. The assessment may have made it obvious that if the project is built, there will be a need for other infrastructure in support of it, such as additional roads or turn lanes, traffic signals, ramps, or parking accommodations. Projections may show that traffic will need to be rerouted in order to avoid conflicts with zoning laws in the impacted area, or proposed access or egress points may need to be relocated. Any potential traffic concerns should be highlighted.

Software

There is a wide variety of software that can be used in the traffic impact assessment process. Traffic and travel speed can be modeled with appropriate simulation software, while the Environmental Protection Agency provides a model, CAL3QHC, for modeling carbon monoxide concentrations resulting from traffic flow. 3D visualizations can integrate information into an animated simulation of the driving experience, and geographic information systems can be used to present the modeled results in a geographic context.

Example of a Traffic Impact Assessment

The exact requirements of a traffic impact assessment vary by the requiring agency. For instance, in the small city of Nashua, New Hampshire, developers are required to submit a Traffic Impact Report that follows ITE guidelines and relies on ITE methodologies (such as for trip generation as discussed above). Every Traffic Impact Report filed with the City of Nashua Board of Public Works must cover these required areas, with the principal purpose of analyzing the capacity of the roadways impacted by the proposed development: safety, circulation patterns, traffic control needs (such as traffic lights, signage, or turn lanes), transit needs or impacts, neighborhood impacts, parking issues, effects on pedestrian and bicycle traffic, service and delivery vehicle access, driveway location and operation, air quality and noise impact, signalized and unsignalized intersections adjacent to the site, and all site access points.

The Nashua Board of Public Works specifies exactly which baseline conditions, at a minimum, must be included in the report for purposes of comparison: peak period turning movement counts collected on a midweek day (Tuesday, Wednesday, or Thursday) from 7 A.M. to 9 A.M. and 3 P.M. to 7 P.M., weekend counts in the case of retail areas that already experience high weekend traffic volume, and in some cases origin-destination studies. Counts should be specific about vehicle type, separating counts for passenger cars and motorcycles (together), single-axle trucks, multi-axle trucks, buses, and school buses. Maps should be provided to show current traffic flow, while analyses demonstrate the roadway's current capacity and level of service. Key locations in the study area (such as intersections and access points, traditionally) should have their accident history reviewed.

Traffic Impact Reports must be delivered to the Nashua Traffic Engineer at least three weeks in advance of a scheduled meeting before the board to discuss its contents. The board defines specific conditions in which Traffic Impact Reports are required: any development that generates 75 trips per hour between commuting peak times (7–9 A.M. and 4–7 P.M.), any development generating 100 trips per hour during any 24 hour period, any development generating 1,200 total trips in any 24 hour period, any permanent roadway closure, any temporary road closure over 14 days in length, and any other development at the discretion of the Nashua Traffic Engineer.

To take one example from Nashua, on Broad Street, an old state highway connecting neighboring towns to the interstate, a local business owner purchased a former barn that had been converted into an antique store before that store folded. The purchase was made with the intent of extensively remodeling the barn and reopening it as a convenience store aimed at both commuters and residents of the neighborhood, which had not had a local convenience store since a fire claimed the previous one some years earlier. Because the store was to open in a neighborhood that was almost entirely residential, consisting of both condominium developments and single-family homes (the only major exceptions being a church and a motel), special attention was paid to the traffic impact.

Trip generation was believed to be fairly low, since the whole business model depended on attracting pass-by traffic, but despite being below the threshold,

a traffic impact report was required because of concerns over increases in pedestrian traffic and the amount of customer traffic and delivery vehicles that would be turning in and out of the store's small parking lot. Eventually, the Board of Public Works and Zoning Board approved the addition of a pedestrian crosswalk with a traffic light that would stop traffic only when a pedestrian was crossing.

The store remained in business for only a short period due to the building owner's eventual insolvency, and after the building had been foreclosed upon by the bank and resold, another plan to repurpose it was brought before the Board of Public Works: to turn it into a Hindu temple for Nashua's growing South Asian population. Here again traffic was the main concern.

The predominantly, if not entirely, non-Hindu Board needed to have it clarified for them that the traffic patterns for a Hindu Temple would not be analogous to those of the neighborhood's Christian church, in that most drivers would be arriving for individual prayer rather than for weekly community services. Traffic would thus be distributed throughout the week rather than the extremely unequal distribution experienced by churches where the focus is nearly entirely on a weekly Sunday service.

The developers argued that for this reason, given the traffic light and pedestrian crosswalk already in place, the parking lot was sufficient for the temple's needs and would not result in cars parked on the street or interfering with the work of snow plows in the winter (a frequent concern on Broad Street, which needs to be plowed early and often because of the commuter traffic volume but has insufficient shoulders for much of its length for snow displacement). The board agreed and approved the plan.

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See Also: Benefit–Cost Analysis of Transportation; Environmental Impacts; Ethical Issues; Highway/Road Capacity; Risk Analysis/Assessment; Spatial Equity Analysis; Traffic Engineering; Traffic Studies and Surveys; Transportation Impacts on Land Use; Transportation Planning.

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Traffic Incident Management

Traffic incidents have become a major cause of congestion and a significant threat to urban mobility. The Federal Highway Administration (FHWA) reported in 2005 that about 25 percent of congestion in the United States is incident related. The Texas Transportation Institute (TTI) estimated that traffic incidents accounted for about 52 percent to 58 percent of the total delays experienced by motorists in all urban areas. Similarly, the Conference of European Directors of Roads (CEDR) reported in 2011 that road incidents account for 10 percent to 25 percent of congestion across Europe. Implementing traffic incident management (TIM) programs has been proven to be an effective way to reduce the duration and impacts of traffic incidents, mitigate congestion, and improve safety.

FHWA defines TIM as

... a planned and coordinated multidisciplinary process to detect, respond to, and clear traffic incidents so that traffic flow may be restored as safely and quickly as possible.

Traffic incidents include any events that affect traffic flow on the roadway, such as disabled vehicles on the roadway or shoulder, vehicle fires, road

debris, emergency roadwork, police activities, and vehicle crashes. Consequently, a variety of public- and private-sector partners are involved in TIM, including law enforcement, fire and rescue, emergency medical services, traffic management agencies, towing and recovery, hazardous materials management, and others.

In the United States, law enforcement agencies such as state police and highway patrols, local police, and county sheriffs are usually the first responders to traffic incidents. Depending on the nature of the incidents, they will request and coordinate services of other partners. For example, fire and rescue teams may respond to fires and hazardous materials spills, while Emergency Medical Services will respond to the needs of primary medical care and transport of victims. Transportation agencies are usually responsible for developing and implementing traffic management plans to protect the incident scene, control traffic, and distribute traffic information to reduce delay and potential secondary accidents related to the incidents.

TIM in Europe also involves a range of government agencies that provide incident response services similar to their counterparts in the United States. Because European countries are usually geographically more compact and more densely populated, European practice in TIM has a more integrated approach. Many European countries have set up a national framework for incident response, and responders from different government agencies usually receive collaborative training programs.

State of the Practice

In early TIM practice, the responsibilities of incident response were distributed to different agencies, and there was no institutionalized framework to integrate efforts of different incident response agencies. Over time, practice has proven that good coordination and collaboration between different agencies play a key role in improving the efficiency and effectiveness of incident response.

In the United States, the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) requires the development and implementation of a Strategic Highway Safety Plan (SHSP) by each state; it also clearly articulates the needs and provides guidance for developing a formalized TIM program. This TIM program

provides clear top-down authorization for resource sharing and joint operations, establishes a chain of command and ensures accountability, guides on-scene operations, and sets up training programs.

TIM programs help improve coordination between traditional incident responders. Over the years, they have also started to foster the formation of multiagency task forces to further integrate efforts of different agencies. For example, the Maryland Department of Transportation, Maryland Transportation Authority, and Maryland State Police, in cooperation with other federal, state, and local agencies, set up the Coordinated Highways Action Responses Team (CHART) as a joint effort to improve real-time operations of Maryland's highway system through teamwork and technology.

CHART operates a variety of traffic incident response units to provide efficient incident response and to restore highway capacity as soon as possible. For example, emergency traffic patrols help detect and locate traffic incidents quickly. Emergency response units then set up overall traffic control at accident locations. Freeway Incident Traffic Management (FITM) trailers, pre-stocked with traffic control tools such as detour signs, cones, and trailblazers quickly set up preplanned detour routes according to the needs.

Regional Traffic Operations Centers (TOCs) and the Statewide Operations Center share incident information with other related agencies and distribute the information to the public through various traveler information systems. A study in 2009 showed that CHART has been able to reduce the duration of incidents by about 25 percent for the last seven years, yielding significant benefits to both motorists and the entire travel environment. Similar efforts can also be seen in other states.

Deployment of advanced technologies has also become an important aspect of new TIM strategies. For example, more closed-circuit television cameras (CCTV) have been deployed along major corridors to enhance automatic and early incident detection and verification. Enhanced 911/automated positioning systems have been used to capture emergency caller's location with higher accuracy. TIM programs work closely with traffic management agencies to distribute incident and traveler information through channels such as variable message signs (VMS), traveler information Web sites, and conventional media. Timely distribution of incident information is crucial

for mitigating congestion related to traffic incidents. New on-scene emergency lighting systems and high-visibility safety markings have been used to enhance the safety of responders and reduce the probability of secondary incidents.

Similarly, recent development of TIM practice in Europe highlights the importance of coordination between different agencies, cross-border cooperation, and application of new technology. For example, EasyWay is a project for harmonized Europe-wide intelligent transport systems (ITS) deployment on main Trans-Europe Road Network (TERN) corridors supported by the European Commission. One of its services is to share information on incident management capacities on the TERN among partner agencies such as the police, road operators, and traffic management authorities. Its long-term objectives include distribution of incident and traffic information among travelers.

TIM Evaluation

Design and implementation of advanced TIM requires significant investment. There is a strong need to evaluate the performance of TIM and present its benefits to stakeholders. It is challenging to estimate the benefits of TIM projects because capturing the impacts of traffic incidents with limited field data is by itself a big challenge. For example, the Texas Transportation Institute's "2011 TTI Urban Mobility Report" managed to directly measure delay using data collected by vehicles equipped with Global Positioning System (GPS) probes but could not assign the delay to any specific causes. Researchers have to use a variety of tools to estimate the impacts of traffic incidents.

Examples range from the simplest static queuing model to more advanced empirical models such as procedures recommended by the *Highway Capacity Manual* and site-specific mesoscopic and microscopic traffic simulation models. Traffic simulation models, if correctly calibrated, allow researchers to collect a variety of system performance data for scenarios both with and without the TIM system implemented to make a meaningful comparison. However, it requires a lot of resources to develop and calibrate a traffic simulation model for a corridor.

Further, it is not practical to use simulation tools to evaluate the performance of TIM on a regional network. Instead, researchers usually use incident duration as a surrogate to evaluate the

performance of TIM systems. The *Highway Capacity Manual* defined the incident duration to be the time elapsed from the onset of an incident to the end of its clearance.

An effective TIM could help with earlier incident detection, more efficient response team dispatching, better on-scene coordination, and shorter clearance time. Shorter incident duration usually implies great time savings for travelers, especially on busy freeways. Therefore, comprehensive and systematic incident data collection plays a key role in TIM evaluation. For example, the CHART program in Maryland has developed a model to capture the benefits (travel time savings, reduction in fuel consumption, and fewer emissions) associated with TIM implementation and continuously monitor the system performance over years using the incident database it builds.

Service Patrols

Service patrols have been proven to be an effective tool for TIM. The patrol team can help detect and verify the incident, protect the scene, set up traffic control, request additional resources if necessary, and support quick clearance of minor incidents. Many U.S. states have set up patrol services. Examples include the Freeway Service Patrol (FSP) programs in California and Florida, the Freeway Incident Response Safety Team (FIRST) in Minnesota, and the Highway Emergency Response Operators (HERO) in Atlanta, Georgia. Significant benefits associated with patrol services have been reported in a variety of studies. For example, overall incident duration has reportedly been reduced by 28.6 percent in Maryland and 12 percent to 36 percent in Salt Lake City, Utah, as a result of service patrols. In literature, benefits are reported to consistently outweigh cost. Some TIM agencies also deploy equipment and responders at key locations near areas that suffer from high incident rates. This strategy of prepositioning resources could complement the service patrols to further improve incident response efficiency. For example, the Tennessee Department of Transportation has deployed Ready Response Trailers stocked with traffic control devices at 15 strategic locations since 2002.

Research on TIM

Significant research efforts have been dedicated to further improving efficiency of TIM strategies.

For example, researchers are developing active corridor management (ACM) strategies to mitigate non-recurrent congestion associated with traffic incidents through proactive measures. ACM strategies require quick detection and evaluation of traffic incidents, and deploy strategies such as dynamic routing guidance, adaptive signal control, variable speed limit, and temporary shoulder use.

Accurate estimate of incident duration plays a key role for the development and implementation of ACM strategies. Many models, ranging from simple linear regression to complicated Bayesian network, have been developed in literature, and researchers are continuously improving their accuracy with new data and modeling tools.

Another widely studied but still challenging research topic is finding the optimal way to divide highway networks into different patrol zones, and the optimal patrol route within each zone to provide the most effective highway patrol services with limited resources. Early researchers solved this problem using a variety of tools, including the classic median models, the maximal coverage location problem (MCLP), the hypercube queuing model (HQM), among others. However, the recent development of highway patrol services requires a dynamic program operated in real time with great flexibility (for example, capability to reallocate resources if some units have been dispatched elsewhere). More efforts in both theoretical and empirical research are needed to address these challenges.

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See Also: Automobile Accidents and Prevention; Emergency Response Systems; Incident Detection Systems, Automobile.

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Traffic Information and Control Systems

Traffic information and control systems monitor the movement of people, goods, and vehicles to ensure their delivery is as efficient and seamless as possible throughout the transportation system network. There are unique control systems for all modes of transportation, including roadways, airports and airways, railways, coastal and inland waterways, and pipelines. The goal is to increase safety, convenience, and capacity of the transportation network.

Traffic Control Systems

The traffic signal, even if it is a simple road sign at an intersection, impacts virtually everyone every day. Individual traffic signals, if implemented and followed out properly, achieve networkwide traffic operations objectives, which consist of intersection traffic signals, a communications network to tie them together, and a central computer or network of computers to manage the system. Techniques to monitor such systems include time-base and hardwired interconnection methods. Coordinating these methods across agencies requires data sharing and agreement upon traffic signal controls.

Roadway traffic control systems are intended to improve safety, increase the operational efficiency and capacity of the roadway, and contribute

to the traveler's overall comfort and convenience. The areas monitored begin small at isolated intersections using signs and markings, and expand to sophisticated traffic control centers, which have the ability to react to changes in the traffic environment. Traffic control systems are used at roadway intersections, on highways and freeways, at ramp entrances to freeways, and in monitoring and controlling wider-area transportation networks.

People accept and even demand traffic signals to ensure safety and mobility. Drivers usually assume that the responsible agency can efficiently operate signals, such as traffic lights, so motorists usually report only the most obvious failures. Inefficiencies can cause longer trip times and higher fuel costs.

Research and applications demonstrate the effectiveness of signal system improvements in reducing delays, stops, fuel consumption, emission of pollutants, and accidents. Certain traffic systems have been termed adaptive, as in they have the ability to alter signal timing in response to both short-term and longer-term variations in traffic. These systems not only provide more effective control of traffic but also require fewer human and financial resources to update the system's database.

Road traffic controls are monitored by the Federal Highway Administration (FHWA), although state and local agencies have their own variations of standards set forth by the *Manual on Uniform Traffic Control Devices* (MUTCD). Traffic controls vary extensively throughout the United States, depending on the type of roadway being traveled and the kind of vehicles passing through. For this reason, consistency in traffic control certification is not found throughout the nation. For instance, the FHWA does not address certification methods for traffic controllers, flaggers, and other traffic personnel because this is deemed a state or local responsibility. Safety is measured by the Occupational Safety and Health Administration (OSHA) and state safety departments.

Other Modes of Transportation

The U.S. federal government has designated airspace as uncontrolled or controlled. In uncontrolled airspace, pilots may conduct flights without specific authorization, such as private pilots or those using recreational aircraft. In controlled airspace, pilots may be required to be in communication with an air traffic control facility to receive instructions on when they may pass, land, or take off.



Air traffic control is but one of many control systems throughout the transportation system network. Air traffic controllers, who work in towers like this one in Billings, Montana, direct aircraft in order to prevent collisions, provide information to pilots, and expedite the flow of air traffic.

Railroad operations serve both freight and passengers. Traffic controls are especially important as these trains, both freight and passenger, travel on the same tracks and almost exclusively rely upon traffic controls to determine the right of way.

Railroads use both semaphore and light signals for traffic control. Semaphores convey visual messages to train operators based on how the train should be managed and operated. Block signaling prevents collisions with preceding or oncoming trains. Track sections are divided into blocks and one train is permitted to occupy one block at any time. Automatic circuitry monitors which vehicle is occupying each block, and the region it monitors could exceed hundreds of miles. These monitors

look for present and oncoming trains to monitor stops and speed. Dispatchers at circuitry boards can monitor these action by watching colored lights on the board and other visual displays.

To control a boat or vessel, occupants rely less upon traffic control devices and more on the use of informational tools, which can tell them longitude and latitude coordinates, the traveling of larger vessels nearby, and weather conditions. Visually, buoys indicate areas that boats can navigate by whether they are lit or not. Lighthouses also provide a landmark for boats to know where land is and to shine a light on the waters. Lighthouses have fog signals and radio beacons, which aid boaters during periods of limited visibility resulting from inclement weather conditions.

Pipelines that carry various materials are also included in the U.S. transportation network. Oil, oil by-products, natural gas, and fertilizers are the most popular goods transported through this network. Valves, pumps, and compressors are the means by which these substances are navigated throughout the pipeline system.

Travel Demand Management

A highly developed system of streets, highways, freeways, and various forms of public transportation serves the cities in the United States. Population and urbanization growth have led to a growing travel demand. The ability to meet this demand and provide new or improved transportation, however, has been difficult.

The wide spectrum of travel demand management actions includes promotion of nonauto modes of travel, special treatment for high-occupancy vehicles (HOV) within designated lanes, preferential parking for HOV, incentives to reduce peak-period travel, telecommuting, nonstandard workweeks (for example, four 10-hour days), and transit service improvements.

Many travel demand management measures impact or depend on the efficient and effective use of traffic signal systems, freeway traffic management systems, and traveler information systems. Efforts to promote transit usage become less effective if, for example, buses meet unnecessary delay from inefficiently operated signals. Vanpool and transit usage become more attractive if these vehicles can travel on less congested HOV freeway lanes. Therefore, urban highway control systems and information

systems prove critical to the overall operational effectiveness of transportation facilities.

In the past three decades, the transportation network in the United States has experienced tremendous growth of advanced traffic control and management systems for both freeways and streets. Computers now control streets and highways, and their functionality has been accelerated by the revolutionary advances and associated cost reductions in communications and electronic technologies.

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See Also: Air Traffic Control; Automated Traffic Control Systems; Highway and Road Safety; Railroad Automation Technology; Traffic Control Devices; Traffic Laws and Enforcement; Traffic Signals.

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Traffic Laws and Enforcement

Traffic laws may be considered a form of civil engineering. Almost solely a product of the 20th century when the United States became an automobile society, traffic laws are codified by states, counties, and municipalities in order to ensure the orderly

movement of traffic and to minimize hazards to safe travel. Enforcement of traffic laws relies upon policing. Forty-nine states in the United States have special police forces, variously designated as highway patrol, state patrol, or state police, who devote a substantial part of their time to traffic duties. Major metropolitan police agencies typically have a traffic division, and local police officers in smaller communities typically spend time not required for other activities in traffic patrol.

Law enforcement officers issue tickets to drivers or other road users who violate traffic laws. Traffic tickets generally are divided into two categories: moving violations (with speeding being the most common) and nonmoving violations (with parking violations being the most common). Although definitions vary from state to state, most traffic tickets are considered infractions. More serious offenses are labeled violations and may be considered misdemeanors or felonies, with the appropriate penalties.

The Need for Traffic Laws

Traffic laws did not originate with the advent of the automobile. Julius Caesar banned wheeled traffic from the streets of Rome during most daylight hours in an effort to relieve congestion. The traffic fatality rate in urban centers in the late 19th century when horse-drawn vehicles clogged city streets far exceeded 21st-century fatality rates in the same areas. It was the accidents caused by these vehicles, not automobiles, that prompted William Phelps Eno, "the father of traffic safety," to invent the "rules of the road" and write a city traffic code for New York City in 1903, the first such code. Eno is credited with devising the stop sign, the stop light, the yield sign, the crosswalk, the pedestrian island, the one-way street, the traffic circle, and the taxi stand.

Soon after Eno developed his plan for New York City, the automobile brought new concerns, and it became clear that regulations for these new vehicles were needed. California made driving an unregistered vehicle and driving without a license a misdemeanor as early as 1905. In the last quarter of 1906, the New York City police arrested 646 people for violations of laws and ordinances related to motor vehicles. States saw the need to require the registration of vehicles well before they became concerned with issuing drivers a license. In 1901, New York became the first state to register automobiles;

by 1918 all states required license plates. By the 1920s, cities, plagued with congestion, accidents, and parking problems, were imposing speed limits, installing traffic signals, designating one-way streets, and restricting parking.

By the end of the 1920s, three-fourths of American households owned a car, but laws governing those who could drive automobiles were inconsistent at best and nonexistent in many cases. In 1903, Massachusetts and Missouri became the first states to issue a driver's license, but no examination was required. As late as 1935, only 39 states required licenses for drivers, and examinations were still the exception among the states that did require a license. Rhode Island became the first state to test individuals on their driving skills before issuing licenses in 1908; New Jersey followed in 1913. The *New York Times*, which had reported concern about accidents due to driver carelessness and inexperience in 1907, expressed the hope that other states would follow, but it was 1924 before New York required either a license or an examination of a driver. As late as 1950, six states still did not require an examination. The last state to require drivers to pass a driving exam was South Dakota in 1959.

Licensing and registration were just a small part of an increasingly complicated issue. The sheer volume of court cases involving violations of traffic laws was creating a burden for the nation's cities. In 1942, an estimated one in eight drivers in the United States went to traffic court, and traffic violations were involved in at least half of all accidents. Automobile accidents were responsible for 30,000 deaths and 1,250,000 serious injuries each year.

Although conviction rates were high, averaging about 80 percent, penalties were low or not imposed at all. Drivers' records were rarely examined, so repeat offenders were not identified. States and cities were faced with rising costs for implementing and enforcing traffic laws required by the transition to the automobile as a primary mode of transportation. The lack of uniformity among the states added to the chaos.

The Uniform Vehicle Code

In 1924, U.S. Secretary of Commerce Herbert Hoover called for the first National Conference on Street and Highway Safety. Representatives from 43 states and various organizations with connections to

traffic safety—nearly 1,000 delegates in all—attended the conference. Many of the reports submitted to this conference noted the absence of uniform traffic laws. In direct response to this concern, Secretary Hoover appointed a Committee on the Unity of Laws and Regulations under the auspices of the National Conference on Street and Highway Safety in April 1925. This committee reviewed, revised, and approved a draft of the codes by the 1923 committee. The full conference repeated the review process, and on August 20, 1926, the first edition of the Uniform Vehicle Code was published. A model for the traffic ordinances of municipalities, based on ordinances of 100 cities, followed in 1928.

The National Committee on Uniform Traffic Laws and Ordinances was created in 1947 and has continued the process of reviewing and revising the code and the ordinance to accommodate changing times. Although states are not bound by the Uniform Vehicle Code, most states have adopted the laws, in whole or in part, as the basis for the laws and regulations related to traffic.

In its early stages, the move toward uniformity of traffic laws was seen as the province of individual states, and the choice to adopt the uniform code was cooperative action. While some laws recommended as best practices in the Uniform Vehicle Code gradually gained widespread adoption, the pace was slow. For example, Indiana passed the first state law defining driving under the influence in terms of blood alcohol concentration (BAC) in 1939, and the Uniform Vehicle Code adopted that law in 1944. But more than a dozen years later, only 30 states had adopted the BAC definition. The 1960s altered the balance between the states and the federal government. The Highway Safety Act and the National Traffic and Motor Vehicle Safety Act, enacted in 1966 in response to soaring numbers of traffic fatalities and the number of cars on American roads, gave the federal government the power to establish safety standards and to require each state to ensure that its rules of the road were uniform within all its jurisdictions and consistent with plans of other states.

Since the enactment of those laws, the federal government has tied the allocation of highway funds to the passage of laws governing implied consent, which says driving a vehicle implies consent to a chemical test to determine BAC level and motorcycle helmet use. The history of the latter

affirms the effect of federal pressure. In 1967, the federal government required that states enact helmet laws in order to qualify for certain federal safety programs and highway construction aid. By the early 1970s, almost all states had comprehensive motorcycle helmet laws, but when Congress ended the Transportation Department's authority to assess financial penalties on states without helmet laws in 1976, state legislatures began repealing the laws.

The Enforcement of Traffic Laws

Traffic enforcement is the most recognizable and universal police function. According to a 1999 Department of Justice estimate, more than half of the contacts between police and citizens nationwide occurred at traffic stops. Speeding is the most common reason for ticketing a driver. On an average day, 112,000 drivers in the United States receive tickets for exceeding the posted speed limit at an average cost of \$152. The total annual cost of speeding tickets is more than \$6 billion. In 2010, over 1.4 million drivers were arrested for driving under the influence of alcohol or narcotics. Most of these tickets were issued by highway patrol officers. In New York State, for example, state troopers comprise less than 6 percent of the state's total law enforcement personnel but issue 55 percent of all speeding tickets.

Doubtless, the fact that about one-fourth of U.S. citizens have received a traffic ticket for a moving violation (speeding, running a red light, passing illegally, etc.) contributes to the American tendency to view traffic violations as "folk crimes" as opposed to "real crimes." Some even argue that ticketing violators does little to deter them, a claim supported by several studies from the 1970s and 1980s that concluded that the level of police enforcement showed no correlation to the vehicle accident rate. More recent studies offer a different view. A 10-year Canadian study published in 2003 concluded that at least in countries with heavy motor vehicle traffic, enforcement of traffic laws reduced the number of traffic fatalities. An investigation of the effect of a 33 percent reduction in the number of full-time roadway troopers in Oregon found that at the same time the national fatality rate was falling, traffic fatalities in Oregon increased by 19 percent, incapacitating injuries by 14 percent, and visible injuries by 12 percent

compared to the three-year period before the layoffs. Studies in three other states reported comparable results. Researchers concluded that enforcement can play a significant role in driver behavior.

The Department of Justice initiative Data Driven Approaches to Crime and Traffic Safety (DDACTS) introduced in 2008 uses traffic law enforcement to address both traffic violations and crime by putting "high-visibility enforcement" in geographic areas that have been identified as having heavier than average concentrations of either. The program uses data collection and analysis to deploy limited resources in the places where that will make the greatest difference. Cities like Baltimore, Maryland, that have used the DDACTS model have seen reductions in traffic crashes and crime.

Technology is changing the process of traffic enforcement in the 21st century. Perhaps photo enforcement is the most controversial of automated enforcement devices. Substantial evidence supports the claim that traffic cameras discourage violators and decrease accidents. An Insurance Institute for Highway Safety study reported a significant decline in red-light running at intersections with cameras and also nearby intersections without cameras as much as a year after the cameras were first used.

As of 2013, traffic cameras were in use in 582 communities nationwide to catch violators who speed, run red lights, or commit other violations. Critics charge that the use of cameras has more to do with increasing revenues than with public safety. A single camera on one busy road brought in more than \$11 million in just two years. Light detection and ranging (LiDAR) has proven superior to traditional radar in detecting speeders because it creates a high-resolution image that identifies vehicle make, model, license plate number, and facial characteristics of the driver. A distance between cars mode makes it possible to document tailgating, an offense notoriously difficult to prove. Electronic traffic citation software is replacing traditional paper tickets and reducing the roadside risk to ticketing officers at the same time.

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See Also: Automated Traffic Enforcement; Driver Licensing; Speed Laws and Enforcement; Traffic Safety and Risk Assessment.

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Traffic Management Systems

Growing populations, urbanization, and globalization are all placing unprecedented stress on transportation networks worldwide. Those who face the challenge of a daily commute in one of the world's large cities know well the complexity and chaos placed on transportation networks.

The developers of traffic management systems (TMS), also known as advanced traffic management systems (ATMS), attempt to bring some order to that chaos. The term *traffic management systems* is a fairly broad term, which is used to describe any number of configurations of components that can be used to alter traffic flows within a metropolitan area. Traffic management systems are a type of intelligent transportation system (ITS); such systems may monitor any type of transportation system in efforts to optimize travel in metropolitan areas.

Elements included in a TMS may include communicating with commuters while they are in their vehicles, real-time traffic monitoring, and incident monitoring. Examples of especially successful traffic management systems can be found in the Minneapolis/St. Paul, Minnesota, metropolitan area and Atlanta, Georgia. Critics of TMS have claimed that their existence has not been scientifically justified,

and that these systems unduly support personal motor vehicles over other types of transportation.

What It Is, How It Works

In North America, an ITS is primarily concerned with automotive transport. Regardless of how individuals feel about America's dependence on automobiles, it is critical that these automotive transportation systems operate in as optimal a fashion as possible.

The operators of ITS in North America attempt to alter traffic flow by providing information to users in a way that will make automotive travel quicker and more efficient. There are six metrics that all intelligent transportation systems use: increasing transportation-system efficiency, enhancing commuter mobility, improving safety for commuters and bystanders, reducing automotive fuel consumption and the environmental cost of said consumption, increasing economic productivity, and creating an environment conducive to ITS markets.

Regardless of how independent people feel in their automobiles, it is possible for a driver to be manipulated. This manipulation is not conducted out of any desire to micromanage the daily routine of drivers. Instead, these efforts are conducted to optimize traffic flow in an area that may be larger than a major city.

When driving on roads controlled by a TMS, this outside manipulation likely comes from a central point that is governed on a top-down management model. The directors of this type of model seek to integrate technology to improve vehicle flow and commuter safety.

While each TMS is different, they all follow the same basic set of rules. All traffic management centers use real-time traffic data from some type of sensor to a central transportation management center (TMC). The sensors that could be used include real-time traffic monitoring sensors, incident monitoring sensors, traffic cameras, ramp meter monitors, and traffic signal monitors, and each of these types of sensors includes many models and variations.

Once the information from the sensors arrives at the TMC, it is processed and a number of actions may be taken by utilizing a variety of output devices. Dynamic message signs (DMS) are stationary traffic control devices that can provide one or more messages. They are capable of giving

either real-time advice, such as accident information, or basic driving reminders, such as “Don’t text and drive.”

Active traffic management (ATM) systems, also known as “managed lanes” or “smart lanes,” are those that change the permissible direction of lanes in efforts to allow for greater traffic flow where needed. Road weather information systems (RWIS) and other automated weather warning systems monitor weather and road conditions and provide commuters with important information regarding road safety. Highway advisory radio utilizes specially designated radio stations to broadcast important information to commuters. Through these systems, commuters can be informed of critical traffic data and take action accordingly.

Examples and Criticisms

Examples of highly functioning TMS systems can be found in Minneapolis and Atlanta. The IRIS (Intelligent Roadway Information System) system serves the Minneapolis-St. Paul metropolitan area. This open-source project is overseen by the Minnesota Department of Transportation and was put into place in 2007. The primary purpose of IRIS is to monitor and manage interstate highway traffic. IRIS assists Minneapolis’s commuters through the use of DMS signs, RWIS monitors, and traffic cameras.

The Georgia Navigator (also known as Georgia NaviGator) serves the Atlanta metropolitan area, where more than half of the state’s population lives. The Georgia Navigator was installed in April 1996 as part of the preparations for the 1996 Summer Olympics.

Georgia Navigator is overseen by the Georgia Department of Transportation. Hardware integrated into Georgia Navigator includes traffic cameras, changeable message signs, ramp meters, and traffic speed sensors. Each of these devices is connected to the centralized transportation management center in Atlanta via buried optical fiber.

When Georgia Navigator was first designed, it was state-of-the-art for its use of video cameras in gauging traffic flow, although most traffic flow observations depended on fairly low-tech sensors embedded in the pavement. Since the installation of the system, video-based systems have become the industry standard. Because Georgia

Navigator was so advanced when it was installed in 1996, even parts of the system that have not been upgraded since then are still fairly up-to-date. Georgia Navigator’s area was extended in the late 2000s to include nearly all of Atlanta’s outer belt and previously unincorporated traffic lights and ramps.

There are those who have criticized TMS and other elements of ITS, claiming that these systems have never been scientifically justified. Therefore, their implementation was based simply on the perception of various individuals about the need for optimization, instead of a scientifically proven need or some evidence that improvement is possible. Critics have also decried these systems for inherently favoring personal motor vehicles over mass transit, such as buses or rail systems, or bicycles or pedestrians.

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See Also: Advanced Traveler Information Systems; Emerging Technologies; Intelligent Transportation Systems; Traffic Detection Systems; Traffic Detection Technology; Traffic Flow; Traffic Incident Management; Traffic Information and Control Systems.

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Traffic Mitigation Programs

Traffic mitigation programs are measures aimed at a reduction of the negative effects of road transportation in urban areas through the management of traffic levels. They usually consist of regulations on the use of some links in the road network or of measures influencing travel demand, the choice of modes of transport, or the assignment of traffic to the network.

The programs address issues such as congestion, environmental quality, road safety, pedestrian mobility, and energy consumption. Despite the potential benefits, these programs face several constraints regarding their effectiveness in influencing traffic levels and behavior, as well as social and political support for their introduction.

Traffic Restriction

Traffic restriction measures limit traffic in some parts of the road network. The limitation can be permanent or temporary (valid only at specific times of the year, week, or day) and can apply to all or some vehicles, depending on their characteristics (for example, size, age, contribution to the emission of air pollutants, or license plate number).

One example of traffic restriction is the limitation of traffic in all roads and streets within a specific area of the city. This policy is known as areawide traffic restriction and is often applied in the city center, with examples found throughout Europe. The restriction may apply to private vehicles only or to all motorized traffic. However, in most programs, the restricted links are open to local residents and, at some times of the day, to freight vehicles.

These measures are introduced as a means to reduce traffic levels and congestion in areas with high concentrations of travel destinations for work, study, or shopping trips, and where the road capacity is insufficient to meet the demand for road space. The policy also promotes the mobility of pedestrians, as the limitation of road traffic is usually applied in conjunction with the “pedestrianization” of some streets.

The reduction of traffic has benefits in terms of reduced accident risk, air pollution, and noise in the areas of application. The introduction can then be justified in terms of social equity, because, in many

cities, the central areas are inhabited by populations particularly vulnerable to deteriorations in pedestrian mobility and environmental quality, including the elderly, low-income populations, and racial minority communities.

Road space rationing is another example of traffic restriction policies. In this case, the restrictions are based on vehicle license plate numbers and apply on certain days of the week only. The measure has been used in Athens, Greece, several Latin American cities (such as Mexico City; São Paulo, Brazil; and Santiago, Chile), and more recently in Beijing, China. The restriction usually applies to road links where congestion is particularly high, such as the main commuting corridors from suburbs to major centers of employment.

Empirical studies show that the application of road space rationing leads not only to the reduction of congestion in the restricted links but also to reductions in the emission of air pollutants at the city scale. By restricting the possibility or reducing the convenience of car trips, the policy may also contribute to a modal shift to public transit or non-motorized modes.

Despite the potential economic, social, and environmental benefits, the introduction of traffic restriction measures often meets with strong opposition. Some of the arguments deal with the loss of freedom for road users, who are forced to reduce the number of trips, change to alternative means of transport, or use alternative routes—leading to increased time and monetary costs and losses in comfort and convenience. Critics also raise doubts regarding the effectiveness of the policy in decreasing traffic-related problems at the city scale, because traffic levels may increase in the roads used as alternatives to the restricted links. In the case of area restrictions, the policy may also lead to an increase in car parking space or in cruising for parking at the fringes of the areas of application. Critics also question the effects of the policy on retail business and employment in the areas of application.

Area Licensing in CBD

Area licensing programs control road use in a section of a city by allowing access only to licensed users. The licenses are granted in exchange for a fee but can also be distributed for free to residents or workers in the area of application of the policy. Bus traffic and other means of public transportation are

often exempted. Area licensing programs are usually applied in central business districts (CBD) or in other areas with high business concentration, employment, and services.

The oldest example of this policy is the Singapore Area Licensing Scheme. The program was introduced in the Singapore city center in 1975. Free access was granted to some vehicle types, including buses, taxis, and high-occupancy vehicles. The program was later extended to a series of expressways outside the city. The system was converted to an electronic road pricing program in 1998.

Other cities have since adopted similar programs, usually called “cordon tolls” and based on the collection of fees for entrance into the city center by a vehicle. Several European cities have implemented cordon tolls, including London; Oslo, Norway; and Stockholm, Sweden.

Area licensing programs address similar objectives to areawide traffic restriction policies, namely, the reduction of congestion in areas where road

capacity is insufficient to meet high volumes of traffic. The restriction of the number of licenses granted reduces travel demand and increases average speeds in the areas of application of the policy. The reduction of traffic levels also improves local environmental quality. Studies evaluating the impacts of the Singapore Area Licensing Scheme provide significant evidence of the benefits of this type of policy, including the stability of traffic, congestion, and emissions of air pollutants.

Area licensing is a type of road pricing program, and, as such, it shares some of the advantages and disadvantages of economic-based policy instruments. The granting of licenses is a source of revenue for the transport authority, which can be reinvested in the improvement of the public transit network. On the other hand, the application of a fee to use roads has important social equity implications because it prices out some users of the system.

Because of these disadvantages, the introduction of area licensing programs and related policies



The earliest known traffic restriction measures were implemented by Julius Caesar in Rome in 45 B.C.E. Carriages and horse-drawn carts created congestion problems, so the center of Rome was off-limits between 6 A.M. and 4 P.M. The policies of today serve the same objective: the reduction of a negative impact generated by peak urban travel demands. As seen in the sky above this typical Southern California rush hour traffic jam, air pollution is one of those negative impacts.

often lack the necessary social and political support. This explains the failure in the introduction of some projects, such as the Edinburgh, Scotland; and Hong Kong, China, electronic road pricing programs.

Traffic Restraint

Traffic restraint programs usually involve a regulated reorganization of city traffic to discourage the use of private vehicles and to promote public transportation and nonmotorized mobility. The programs are usually presented as an alternative to both regulatory instruments restricting traffic and to economic instruments (such as area licensing programs and road pricing) because of the limitations on the social and political feasibility of these policies. The main objective of traffic restraint programs is to influence people's travel decisions in order to arrive at a desirable level of total traffic or modal split between motorized and nonmotorized travel and between private and public transportation.

The use of traffic restraint as a strategic means to control travel demand has been used in Paris, France, since the beginning of the 21st century, with generally positive results. The program has been applied at the metropolitan level and includes several interrelated measures to make public transportation, walking, and cycling more attractive when compared with car travel. Interest in the application of some of these measures has also grown in other cities throughout the world.

A common traffic restraint measure is the reassignment of road space between various road users. This involves the reduction of the number or the width of general-use vehicle lanes and the increase of the number of bus and bicycles lanes and/or the widening of pedestrian pavements. The policy brings clear benefits to the mobility of users of nonmotorized modes and public transportation. However, inefficiencies can be created if the new lanes are used below their capacity and if congestion is increased in the general-purpose lanes.

Car use can also be limited by parking policies. This involves, for example, the reduction of the number of parking spaces, including the implementation of new bus or bicycle lanes and widening of pedestrian pavements. The increase of parking fees is another possibility for decreasing the attractiveness of car travel in urban areas. The benefits of these policies are, however, dependent on the sensitivity of car

users to the availability and price of parking. In addition, congestion and pollution may increase as some drivers spend longer times cruising for parking.

Changes in speed limits are another instrument of traffic restraint, with a growing number of examples of cities introducing speed limits of 12 miles per hour (20 kilometers per hour) or 19 mph (30km/h) in some residential areas. In recent years, the policy has started to be introduced at the level of whole administrative areas. This is, for example, the case of Islington, a ward in central London, where the entire street network has a speed limit of 20 miles per hour, including not only side streets but also main roads. The reduction of speed limits has obvious benefits in terms of road safety for car users, cyclists, and pedestrians. However, critics have expressed concern about the effect of this type of policy on overall congestion and air pollution emissions.

Traffic Avoidance

Traffic avoidance programs are policies that promote the reduction of road traffic through the substitution of some of its functions. These policies are usually subject to less social and political protest, because they do not seek traffic reduction through the direct regulation of the transport sector and, as such, they are not restrictions to the choices of households and firms in the transport market. The target of these programs can be passenger or freight travel.

Policies directed at passenger travel may aim at a reduction of the need to travel or at a change in trip frequencies. The measures are not specific to transport planning but are instead an element of policies in other sectors, such as employment, education, and public administration. One example is the promotion of programs and activities that reduce the number of total trips, such as work-from-home (also known as telework or telecommuting), distance learning, videoconferencing, Internet shopping, and electronic government. An alternative policy is the promotion of programs that modify the temporal pattern of passenger trips in order to distribute these trips evenly throughout the day and reduce congestion in peak periods. An example of this type of policy is the provision of incentives for firms to implement flexible work time schedules.

Policies can also aim at a change in the means of transportation used to access certain destinations. This is, for example, the case of measures to promote

ridesharing (that is, the use of cars or vans to transport workers accessing the same area). This policy reduces traffic levels for the same number of passengers sharing. Ridesharing trips can be organized by companies that provide vehicles and link passengers traveling to the same destination. Programs can also be organized by companies for their employees or by large retail shops for their customers.

Freight traffic can also be influenced by traffic avoidance policies. The reduction of this type of traffic is an objective of special importance in road traffic management because large freight vehicles are responsible for more congestion, noise, and air pollution than other vehicles. Public policies in this field usually aim at encouraging freight firms to shift from air and road transport to less polluting means, such as rail and water. This can be achieved by improving rail and port infrastructures or providing tax advantages to firms using these means of transport. Other policies aim at a reduction of road freight transport by promoting more efficient distributional channels, for example, by reducing the number of trips by changing scheduling and routing.

Traffic avoidance policies in the freight transport sector operate at a global, national, or regional level. At the city level, there is a smaller scope for reducing the number of trips or changing transport mode because freight transport serves a large number of businesses dispersed throughout the city. The policies, in this case, focus on creating conditions for the firms to change delivery times, with the objective of avoiding high volumes of freight traffic during peak commuting hours. This involves, for example, the restriction of freight vehicles in some areas of the city at some times of the day.

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See Also: Automated Road-Pricing and Toll-Collection Systems; Automobile Access Programs; Congestion Mitigation and Air Quality Program; Cordon Travel; Parking Planning and Management; Road Pricing Schemes, U.S. and International; Telecommuting and Telecommunications; Traffic Demand Management.

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Traffic Monitoring

Traffic monitoring relies on the use of such tools as helicopters, remote video, and sensors to collect a variety of data, including the number, type, and weight of vehicles. Traffic monitoring utilizes both older intrusive technologies, such as sensors embedded in roadbeds or surfaces, and newer nonintrusive methods, such as the use of traffic helicopters and remote video cameras. Traffic monitoring occurs at the local, state, and national level in many countries and is most widely used in urbanized areas. The general public, the media, government, and traffic engineers all utilize traffic monitoring data.

Increased vehicle ownership and travel, suburban growth, and reliance on highways for commercial transportation in the post-World War II period resulted in highway construction and roadway congestion. Computing revolutionized traffic monitoring technology in the late 20th and early 21st centuries, leading to the development of nonintrusive traffic monitoring; larger, more comprehensive data sets; faster, safer, and less expensive data collection and analysis; and the design of intelligent transportation systems (ITS). These developments have also facilitated traffic monitoring in urban and metropolitan areas most prone to traffic congestion.

Data gathered through traffic monitoring can include traffic flow, vehicle and axle counts in multiple lanes, vehicle speeds in multiple lanes, vehicle weights, axle loads and spacing, intersection or ramp movement counts, the presence of and alerting to accidents or stopped or disabled vehicles, wrong-way vehicles, and other potential traffic hindrances such as severe weather. Newer traffic

monitoring technologies can detect additional data such as vehicle occupancy, points of origin and destination, and travel times. The analysis of traffic monitoring data is vulnerable to problems such as the inherent unpredictability of traffic movements.

Traffic Monitoring Methods

The use of helicopters and remote video is characterized as nonintrusive traffic monitoring systems because there is no required installation of components within the roadbed or surface. Remote video cameras are most often located on structures or poles, and are most often employed along freeways, major arteries or intersections, or other highly-traveled locations. Remote video detection systems can compare images captured from these cameras with programmed baseline images to automatically detect anomalies such as traffic congestion.

Traffic helicopters and remote video systems aid in traffic monitoring by providing real-time visual traffic information. Radio and television news and morning shows routinely employ traffic helicopters and remote video to provide real-time information and footage on daily commuter routes and potential problems, such as accidents, road closures, and weather conditions.

Sensors are considered intrusive traffic monitoring systems because they must be installed within the roadbed or road surface. Traffic engineers record, transfer, and analyze the recovered sensor data. Data samples from specific roadway sections or time allotments are extrapolated to estimate traffic information for entire roadways (or years) as a more cost-effective method than placing sensors and gathering data from every roadway section at all points of the year. Early types of sensor technology employed in traffic monitoring that are still in use include manual observation and data collection, pneumatic road tubes, and inductive loop detectors. Pneumatic road tubes record the number of vehicles passing a particular location.

Inductive loop detectors remain among the most employed traffic data collection methods. They are embedded within the roadbed and measure and record information as vehicles travel through the resulting magnetic field. This information may include vehicle speed, length, and weight, as well as the distance between vehicles.

Newer sensor technologies include strain gauges, capacitance pads, load cells, piezoelectric sensors,

and automated vehicle identification sensors. Newer in-vehicle devices are also increasingly popular tools in traffic monitoring. Radio frequency identification devices (RFID), often used for automatic toll collection, use travel time between sensors to provide estimates of vehicle speeds, while the Global Positioning System (GPS) can provide vehicle positions and speeds. RFID devices are also sometimes used for traffic light sequencing along with image processing and beam interruption systems.

Traffic Monitoring Uses

Traffic monitoring improves traffic flow and capacity while reducing traffic congestion and fuel consumption. It also aids in safety and improves emergency response times to accidents, disabled vehicles, and other incidents. Personal and community benefits include improved navigation, optimal route planning, access to real-time or almost-real-time traffic information, reduced fuel costs, and reduced stress and related incidents of so-called road rage. Traffic monitoring data can also be commercially marketed.

Traffic engineers use traffic monitoring data in the complementary field of traffic control and calming. The data helps traffic engineers develop and implement such strategies as traffic signal timing, ramp metering, high-occupancy vehicle (HOV) systems, rapid incident response, congestion pricing schemes, and roadside assistance programs. Traffic engineers and urban planners also utilize the data in urban design, roadway planning and construction, and traffic emissions reductions and other environmental programs.

Traffic reporting allows media outlets, such as radio and television news programs, to provide near-real-time traffic information for their listeners and viewers. Traffic reports are especially prevalent during the morning and evening rush-hour periods. Traffic helicopters sometimes help break local or national news through coverage of traffic chases involving law enforcement. Media organizations in large national or metropolitan markets often employ their own traffic helicopters, while media organizations in smaller markets often rely on private contracting services to reduce costs.

Various traffic monitoring technologies are often developed and employed based on cost/benefit and cost-effectiveness analyses, because they often require both financial and personnel expenses. Cost

and risk analysis looks at initial and ongoing financial investment, safety issues, technological and other challenges, and environmental impacts. The economic crisis that began in 2008 and its resulting budget constraints, coupled with public pressure for cost-cutting measures, have reduced funding and staff in many state and local governments, leading to cuts in programs such as traffic monitoring.

Intelligent Transportation Systems

Computing advances, most notably in the fields of microcomputing, wireless communications, and advanced vehicle electronics, led to the development of ITS technologies, which began to influence the traffic monitoring and control fields by the early 21st century. Real-time traffic monitoring data and properly equipped vehicles are essential to ITS functionality. ITS uses include automatic traffic law enforcement devices, such as red-light cameras, speed alerts, and automatic license plate number recognition, and electronic systems, such as informational highway electronic bulletin boards.

In-vehicle uses include the selection of optimal routes, the availability of electronic maps and other traffic data through GPS or other systems, and emergency vehicle assistance notification systems, such as OnStar. New ITS technologies and growing use of traffic applications for smartphones, which allow drivers to directly share information through mass social networks, may reduce future demand for media traffic monitoring and reports.

Potential ITS features utilizing traffic monitoring data include completely automated vehicles and infrastructure systems, the roadside-to-vehicle transmission of traffic and related conditions, and car-to-car communications systems. Satellites and other technologies also have potential use in future traffic monitoring and ITS.

ITS technology is emerging on the global stage as well. Networks such as ERTICO-ITS Europe, ITS Japan, and ITS America promote ITS development and implementation in their countries or regions and jointly host an annual ITS World Congress.

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See Also: Helicopters; Information Technologies and Transportation; Intelligent Transportation Systems; Traffic Detection Systems; Traffic Detection

Technology; Traffic Engineering; Traffic Incident Management; Traffic Information and Control Systems; Traffic Management Systems.

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Traffic Noise Abatement

Noise associated with transportation has progressively become a nuisance to communities along roads. As transportation of people and goods continues to grow, roads expand and noise levels rise. Transportation agencies have become more environmentally sensitive and ready to deal with pollution problems, including noise.

A number of factors affect the level of traffic noise, such as vehicle speed, terrain, grade, surface absorption, and shielding provided by walls, fences, buildings, or even dense vegetation. The most frequently used noise abatement measure has been the construction of noise barriers on the side of the road. Such barriers are normally built along highways that carry heavy traffic in urban areas, where noise pollution is likely to be higher and affect more people.

Because of their high cost, however, traffic noise barriers are not typically placed in rural areas, where not as many people are affected by noise, or on low-volume roads, where the noise levels are not consistently high. Even for residents and businesses near the barriers, however, the noise abatement is only effective in the acoustic shadow of the wall. Other receivers of the sound are affected as much as they were without the barrier.

In recent years, there has been a growing interest in designing and constructing quieter pavements to abate traffic noise by reducing the noise at the source. Some alternative abatement measures include the use of buffer zones, managing of traffic, and installing noise insulation in buildings.

Noise Barriers

Noise barriers are normally solid-wall structures built between the highway and the impacted activity area. Barriers do not eliminate the noise; they only reduce the noise levels for certain benefited receivers (people within hearing distance), normally those in proximity to the road. Barriers are especially effective for those receivers situated directly behind it, who can experience a decrease in noise level of typically 5 to 10 dBA (A-weighted decibels).

Noise barriers are not effective for homes on a hillside overlooking a road or for buildings that rise above the barrier; the barrier must be high enough and long enough to block the view of the road.

Common materials for barrier construction are concrete and masonry; other materials are metal and acrylic. Such barriers are mostly reflective. Absorptive materials can also be used and these include panels with mineral wool or other fibers inside them. The height, length, and material are key components to the effectiveness of the barrier. Openings in the barriers, such as those designed to allow access to side roads or driveways, decrease their effectiveness.

Many barriers reduce visibility and lighting; in such cases, transparent materials can provide a solution. Barriers could also present a problem for businesses along the road by restricting views and access by customers. Normally, transportation agencies invite public involvement in the decisions about barrier design and construction.

Quieter Pavements

The sound generated by highway traffic comes from various sources, namely, tires, pavement, engines, exhaust, and brakes. At highway speeds, tire/pavement noise is the major component of traffic noise. By utilizing quieter pavements, the noise is eliminated at the source. The properties of tires and pavements have a significant role in noise generation.

Pavements are designed for safety and durability; it has been shown that both asphalt and concrete surfaces can be designed to be quieter. There is a wide variability in pavement characteristics, resulting in a broad range in noise levels generated by traffic; the main pavement properties linked to noise are texture, porosity, and stiffness.

Texture is important for proper friction and skid resistance, which are basic safety features of all pavements. Small and smoother textures are usually related to quieter surfaces. The voids in the

pavement provide drainage to the surface, another fundamental safety characteristic, but the voids also absorb noise. The stiffness of the pavement surface has an effect on noise, and harder pavements are generally louder. Softer materials, such as rubber, are sometimes included in pavement mixes to make them quieter.

Asphalt pavements that are open-graded are generally quieter than their more conventional dense-graded counterparts. Open-graded asphalt mixes are generally characterized by a large percentage of one size of coarse aggregate (usually 1/2 or 3/8 inch maximum particle size), little or no fines, and a high percentage (15 to 25 percent) of air voids in the mix. The voids provide channels between the angular surfaces of the aggregate to allow rapid drainage of surface water. This prevents hydroplaning and provides maximum skid resistance, while also reducing splash and spray, improving visibility of stripes and pavement markers, and reducing glare from headlights while driving at night under wet road conditions.

Studies have found that open-graded surfaces can reduce roadside noise levels by 3 to 7 dBA, when compared to dense-graded asphalt pavements. A disadvantage of open-graded pavements could be the decline in their acoustic durability over time, which sometimes occurs because voids tend to get clogged by debris and compacted by traffic loads.

Concrete pavements can be made quieter by using proper texturing and finishing techniques after the concrete has been placed. The use of common texturing procedures, such as transverse tining, typically results in loud pavements; instead, texturing alternatives, such as carpet drag and diamond grinding, have produced quieter surfaces.

Other Noise Abatement Measures

Buffer zones are areas of undeveloped open spaces between a highway and the residences. Agencies can purchase land for noise abatement. However, buffer zones are not frequently used, because a large amount of land is typically necessary for them to be effective, and in many cases, residences already exist close to the roads. Vegetation can be used to mitigate noise, if it is dense, high, and wide enough to protect the receivers. However, it takes about 200 feet of dense vegetation to audibly reduce traffic noise, and its effectiveness is therefore limited. Trees provide a visual shield and some

psychological benefit, but are not acoustically comparable to a solid barrier.

Certain methods of traffic management can reduce noise levels. Reduction of speed limits can be implemented as a way of mitigation; a 10 mile-per-hour reduction in speed normally represents a 2 to 3 dBA decrease in noise levels. Trucks are usually responsible for a main part of traffic noise. Typically, one truck generates the same acoustic energy as 10 passenger cars. Trucks can be prohibited from certain roads, or they can be permitted to use those roads only during daylight hours. Traffic lights can be changed to smooth out the flow of traffic and eliminate the need for frequent stops and starts.

Mitigation measures can also be performed by affected receivers, which include insulating, caulking, replacing windows and doors, installing weatherstripping, utilizing air conditioning as an alternative to opening windows, and making other improvements to private structures. Finally, the geometric design of the road could be tailored to reduce traffic noise, as braking, accelerating, climbing, and turning will all increase noise to varying degrees.

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See Also: Neighborhood Disruption From Highway and Transit Construction and Operations; Noise Pollution and Cars; Traffic Mitigation Programs.

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psychological processes underlying that behavior. While many external factors influence traffic efficiency and safety, internal factors are also significant. There are several models that are drawn from social psychology, such as planned behavior, driver stress, risk compensation, and personality theory. These and other theoretical aspects of psychology are applied to improve traffic mobility and increase safety on the roads.

According to the National Highway Traffic Safety Administration's (NHTSA's) "Traffic Safety Facts 2010," approximately 5,419,000 crashes (fatal and nonfatal) occurred in the United States in 2010. According to the International Association for Applied Psychology (IAAP), there are approximately 1.3 million fatalities on the world's roads every year; estimates of annual nonfatal crash injuries vary between 23 million and 34 million people.

Expanding Field of Study

Traffic psychologists strive to understand the mechanisms that may explain a driver's dynamic behavior. Areas of research in this field include variables that affect traffic relative to driver behaviors, such as decision making, demographics, distraction and inattention, drug and alcohol use, training and experience, habits, familiarity with vehicle and environment, fatigue, spatial cognition, perception-reaction time, and panic responses. Another large area of research involves risky behaviors when driving, such as hurry, social pressure, narcissism, competition, anger, aggressiveness, thrill seeking, listening to music, talking on the phone, and texting.

The study of traffic psychology also encompasses possible countermeasures that can be used to reduce risk from these behaviors. Prosocial behaviors, such as courtesy and cooperation, and socially influenced behaviors, such as conformity, are also being studied. Traffic psychologists are highly motivated to seek greater understanding of human behaviors and to uncover ways of reducing the global toll of death and injury on the world's roads. This field of applied psychology continues to gain in relevance and importance.

Global Awareness

The 5th International Conference on Traffic and Transport Psychology (ICTTP) took place in Groningen, the Netherlands, in August 2012. (The 6th International Conference will be in Brisbane,

Traffic Psychology

Traffic psychology is a widening field in psychology that studies the behavior of road users and the

Australia, in 2016.) Partially sponsored by the International Association of Applied Psychology (IAAP), the symposium focus was on “Traffic and Transport Behaviour: Interaction Between Theory and Practice.” Presentations at the conference included research in the areas of behavioral adaptation, elderly drivers’ behaviors, risk and hazard perception, driver attention and road design, effects of personality, gender, and age on driving behaviors, road safety education, and behavioral modeling and adaptation.

Another internationally known group that is devoted to the study of driving safety and psychology is the Global Road Safety Partnership, initiated by the World Bank Group in February 1999. The partnership is dedicated to the sustainable reduction of road crash death and injury in low- and middle-income countries, which suffer 90 percent of the 1.3 million annual deaths and more than 30 million serious injuries that arise from road crashes.

Applications of Psychology to the Modification of Driver Behaviors

Psychologists generally divide human learning and behavior into three domains: cognitive behaviors (mental skills or knowledge); affective behaviors (feelings and emotions or attitude); and sensorimotor or psychomotor behaviors (manual or physical skills).

Studies and research on cognitive behaviors deal with data recall, comprehension, and application of knowledge. Examples of some of these behaviors as they relate to driving would be evaluating, interpreting, and applying information and justifying situations. Affective behaviors, on the other hand, deal with emotions, values, and motivations. Examples of these behaviors as they relate to driving would be selected attention, recognizing responsibility, and prioritizing the taking of risks.

Sensorimotor or psychomotor behaviors deal with sensory input, environmental cues, and perception or awareness. As related to the study of driving behaviors, these would include reaction times, mechanisms or learned responses, complex responses (learned skill sets), and adaptations or modifications.

In the past, research in traffic psychology has used engineering perspectives focused on road and motor vehicle design to enhance safety outcomes of driving. Early studies in traffic psychology addressed driver error, primarily in areas of driver



Traffic psychologists study the behavior of drivers in the hope of reducing traffic accidents. Behavior research in the field deals with subjects such as personality and gender differences, age and skill differences, attention, and violation of traffic rules.

impairment caused by inattention, fatigue, and drug and alcohol use. Currently, focus is on a broader set of psychological variables, such as perceptual styles, personality traits, decision-making skills, and attitudes and motivations. Present research shows that factors contributing to driver behavior include age, gender, education, driver type, risk-taking personality, perceived risks of traffic violations, and acceptance of risk for traffic violations. Important predictors of intentions to commit traffic violations are found to be risk perception, risk acceptance, past behaviors or habits, and perceived control.

Approaches that may be applied to address and modify driver behavior include stricter enforcement strategies, incentive programs that increase drivers’ awareness of risk (and decrease their willingness to accept risk), and compulsory driver training or rehabilitation courses. Research at present is rigorously focused on developing more strategies to modify driver behaviors.

Aggressive Driving Behaviors

Traffic and driving behaviors are frequently studied in conjunction with accident research in order to assess

causes of accidents. While it is unknown exactly how many fatal and nonfatal traffic injuries are caused by aggressive driving, estimates indicate the number to be substantial. This view is based on the types of violations committed by drivers of vehicles involved in crashes as reported by law enforcement agencies to be the contributing factors of the crashes.

By law, aggressive driving is defined as a progression of unlawful driving actions such as speeding, improper or excessive lane changing, or improper passing. The aggressive driver fails to consider the human element involved. There is a difference between aggressive driving and true road rage. Aggressive driving is a traffic offense; actual road rage is a criminal offense. Road rage is defined as an assault with a motor vehicle or other dangerous weapon by the operator or passenger(s) of a motor vehicle or an assault precipitated by an incident that occurred on a roadway. Road rage requires willful and wanton disregard for the safety of others.

Aggressive driving is sometimes considered road rage by the media and by those offended. Many people on the road have experienced other drivers who weave recklessly in and out of traffic, drive too fast on crowded highways, tailgate, scream out their windows, use obscene gestures, or even force other vehicles off the road.

Because driving is so embedded in our recent culture, some individuals feel a sense of entitlement to the road. The anonymity of being behind the wheel gives aggressive drivers a false sense of control and power; therefore, they seldom take into account the consequences of their actions.

Countermeasures

In an NHTSA survey, participants ranked the following countermeasures, in order, as most likely to reduce aggressive and unsafe driving behaviors: (1) more police assigned to traffic control, (2) more frequent ticketing of traffic violations, (3) higher fines, and (4) increased insurance costs.

Increased police enforcement was rated number one both for effectiveness and as a measure acceptable to the public to reduce unsafe and illegal driving.

There are a number of road rage tests and driver personality quizzes available for the public. The designers of these questionnaires are obviously looking for traits of unmanaged anger. Participants answer questions about (or rate) behaviors that they may have engaged in or thought about engaging in.

Examples of the behaviors test takers are asked to consider include mentally condemning other drivers, verbally denigrating other drivers to passengers in the car, closing ranks (using the stare-ahead strategy) to deny someone entering your lane, giving another driver a dirty look, speeding past another car or revving the engine as a sign of protest, preventing another driver from passing, tailgating or pressuring another driver to go faster or get out of the way, fantasizing about physical violence against another driver, yelling at someone through the window, or making a visible obscene gesture at another driver.

If the test uncovers a proclivity for public displays of aggression on the road, the driver is given various types of advice, most of which encourages the participants to think ahead and modify their own behavior. A few techniques are suggested, such as relaxation breathing, listening to music, and avoiding driving when upset or fatigued.

To modify one's behavior, it is also suggested to choose one behavior at a time to practice. This could mean any of the following modifications: leave home 15 minutes earlier than usual (to avoid time pressures), increase following distance behind vehicles, drive less frequently in the passing lanes, reduce cruising speed by 5 to 10 miles per hour, consciously avoid getting angry when forced to brake by another motorist, avoid feeling hostile when progress is impeded by congestion, and/or avoid retaliation when another driver insults you.

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See Also: Automobile Accidents and Prevention; Distracted Driving; Highway and Road Safety; Traffic Safety and Risk Assessment; Traffic Studies and Surveys.

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Traffic Safety and Risk Assessment

An alarmingly high number of vehicle accidents result in serious injuries or death, which makes assessing the risks involved with traffic ever important. The National Highway Traffic Safety Administration (NHTSA), a component of the U.S. Department of Transportation (USDOT), maintains that safety is its primary focus, resulting in a constant focus on data collection and evaluation to implement strategies to reduce and prevent the number of crashes and fatal accidents that happen on the road. This occurs through legislative strategies (laws), law enforcement, and driver-awareness campaigns.

Speeding and Aggressive Driving

Exceeding the speed limit by more than 10 miles per hour (mph) is classified as speeding by NHTSA. Speeding often coincides with aggressive driving, which is defined as “an individual who commits a combination of moving traffic offenses so as to endanger other persons or property.” Drivers, with regard to speeding, are divided into four categories:

1. Incidental and non-speeders, who speed on a small number of trips and for only a small portion of the trip
2. Situational speeders, who speed a lot on a small number of trips
3. Regular and casual speeders, who speed a small amount on a large majority of their trips
4. Habitual speeders, who speed regularly for large portions of their trips

Studies show that it is fairly common for drivers to speed to some extent on any given trip, although some drivers never do at all. It has also been found that weekend and morning trips are most commonly

associated with speeding. Despite the fact that young males have been proven to speed more than other demographics, speeding itself is not limited to any gender or age demographic. Similarly, speeding is not defined by a driver's attitude toward reckless driving or limited to rural or high-speed roadways.

There are many situational factors that influence speeding, including the type of trip, length of trip, presence of other passengers, a driver's propensity to run late, the presence of law enforcement, opportunity, road conditions, and geographic location. Focus groups show that drivers consciously choose to speed, despite knowing safety or speeding tickets could be a potential consequence, which shows how strong a role situational factors play.

Speeding overall is certainly not limited to certain demographics, although some may be more inclined to speed than others. Young males, as previously stated, are the most likely to speed, and males as a whole speed more than females, in particular, older females. Because no demographic alone is immune to speeding, it is believed that personal traits, such as attitudes toward driving, or situational factors influence all demographics. The four classes of speeders are not well defined by demographics, because drivers from all demographics are somewhat equally represented in all groups.

Location and type of vehicle being driven play a large role as well. One study noted that in Texas, driving a truck or a sports car puts you at a greater risk for speeding, but the opposite was found in Seattle. Although not true in Seattle, the trend in Texas is that being associated with affluence (as symbolized by those vehicles) led to greater instances of speeding. Geographical opportunity and regional attitudes influence these drivers.

Although difficult to measure, driver beliefs and attitudes are found to be significant predictors of speeding. Factors such as aggressive driving, inattentive driving, and bad driving habits are often associated with increased risks of speeding. Some factors, however, that logically would be associated with speeding, such as making frequent driving mistakes, prove to show inexperience with driving and therefore less speeding. The following three factors sometimes correlate with speeding:

1. Reckless driving, which includes dangerous violations such as driving drunk, racing, and tailgating

2. Road rage, which shows hostility and anger toward other drivers
3. Dangerous driving, which includes risk-taking behaviors such as running yellow lights and cutting off other drivers.

Traffic Crashes and Risks

Traffic crashes and collisions occur when a vehicle hits another car, person, object, or debris. Although often resulting in injury to passengers or damage to vehicles, accidents can, and often do, cause death, which makes measuring, assessing, and preventing their cause significant.

NHTSA developed the Fatality Analysis Reporting System (FARS) in 1975 to create a database of fatal crashes in the United States and their characteristics. The goal of FARS is to evaluate the effectiveness of safety standards and provide objective solutions for failures in those standards. Data is collected by all 50 U.S. states and must involve a motor vehicle traveling a road that is designated for motor vehicle travel and include the death of a person. To date, FARS has collected data on nearly 1 million vehicle fatalities.

This data collection is critical to NHTSA and USDOT's overall mission to improve safety and reduce the number of traffic-related crashes and deaths. Human factors in accidents include behavior, impairment, and limited visual accuracy. Fifty-seven percent of crashes are caused by factors related to the driver, according to a 1985 study. Overconfidence in one's driving ability is very often the source of factors related to driver-caused accidents.

The Federal Highway Administration has evaluated risks involved in traffic accidents. Evidence shows that, in relation to speed, the following hold true: (1) the risk of having a crash is increased for both vehicles, (2) the risk of being injured increases exponentially with speeds much faster than the median speed, (3) the severity of a crash—and potential fatality rate—depends on the vehicle's speed upon impact, and (4) crashes related to speed involve a speed rate that is too fast for current driving conditions. Reducing speed limits and their enforcement normally does reduce the risk of crashes, although data can be contradictory. While some studies show a correlation between reduced speed limits and reduced number of accidents, others show that speed limit reductions may just

reduce the speed of drivers but not necessarily their risk or potential to crash.

Risk assessments are particularly significant to the auto industry and auto insurance industries. Many studies have found that despite improvements in automobile design, the result has not been a significant decrease in accidents, injuries, or fatalities.

Antilock brakes, for instance, have proven in many studies to seemingly encourage drivers to drive faster, follow the car in front of them closer, and brake as late as possible. However, one safety device has saved countless lives. A 2007 study by the NHTSA showed that in the nearly two decades between 1985 and 2002, there was a significant reduction in the fatality rates for vehicle occupants who wore seat belts.

The NHTSA also tracks data on driver impairment, such as from drugs or alcohol. In 2010 alone, more than 10,000 people died as a result of alcohol in motor vehicle accidents—one person every 51 seconds. Physical impairment, such as auditory or sight problems, sleep deprivation, and age, in particular with novice young drivers and elderly drivers, play significant roles, as well.

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See Also: Automobile Accidents and Prevention; Automobile Safety Systems; Distracted Driving; Impaired Driving; National Highway Traffic Safety Administration; Road Rage.

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Traffic Signal Priority

Traffic signal priority (TSP) is a tool to improve service and reduce delays for priority vehicles, usually mass transit vehicles, at intersections controlled by traffic signals. The sensors at intersections detect an oncoming bus utilizing an onboard device and make adjustments in the signal timings to move the bus through the intersection as quickly as possible without adversely impacting the rest of the traffic. TSP allows for faster, more reliable, and more cost-effective movement of transit vehicles in a congested corridor. It could be used for bus, tram, or light rail lines.

Deployment of TSP is an essential aspect of bus rapid transit (BRT) systems, which rely on fast and reliable service. It should be noted that TSP gives priority, not preemption, to transit vehicles. While preemption interrupts the regular signal process, priority only modifies the process to better accommodate the transit vehicle. There are many technological aspects that need to be thoroughly understood and analyzed before arriving at a decision on what type of TSP system needs to be implemented. Its use is common in Europe and is rapidly growing across North America.

Benefits of TSP

There are several benefits of using TSP, including improved transit reliability, reduced transit travel times, reduced stops (less wear and tear on equipment), increased rider comfort, and reduced emissions. Because TSP allows for smoother flow of transit vehicles, they can move from point to point, as well as to final destinations, on time more often.

Research shows that this increased reliability is a critical need for any transit to become successful. Because the vehicles are sitting on red signals for a much smaller amount of time, the trips can be faster, making transit attractive for riders. This reduction in travel time can also allow for fewer buses to serve a particular route, which can result in reduced operating costs. When vehicles do not stop at every signal, the wear and tear on the vehicle and equipment, as well as that of the pavement, is reduced.

Vehicular emissions result from a combination of distance traveled, speed, acceleration, deceleration, and fuel, among other factors. A smoother flow facilitated by TSP can give the vehicles a relatively constant speed and less need for frequent

stops, acceleration, and deceleration—resulting in reduction in emissions. An aggressive level of prioritizing transit over general traffic, as seen in many European countries, can reward transit usage and help reduce traffic congestion.

The cost of TSP is mainly attributed to equipment. Sensors and communication equipment need to be installed at intersections, as well as in vehicles. Complex designs and greater functionality can increase the cost. Another important expense is to upgrade the signals and controllers. Further cost is incurred in setting up control centers and training personnel.

TSP Methods

TSP can be employed on a location-to-location basis or on a systemwide basis. Systemwide TSP requires the employment of advanced technologies—one example is an automated vehicle location (AVL) system.

Passive TSP techniques involve optimizing signal timing or coordinating successive signals on a corridor. This technique allows for longer green time on the main street and a series of signals that stay green, which will allow the transit vehicle to move along smoothly. This can perform well when there is a significant amount of transit service on a street with high frequency. Passive techniques are cost-effective measures because they do not require specialized technology (for example, bus detectors).

There are several TSP treatments possible, including passive priority, early green, green extension, actuated transit phase, phase rotation, phase insertion, and adaptive real-time control. The most commonly used TSP strategies for buses operating in mixed flow are green extension and early green.

The early green strategy is usually applied to reduce the time for a bus to wait at a red traffic signal. It shortens the green time of other road approaches to expedite the return to green for the approach where the presence of a TSP-equipped vehicle has been detected.

Green extension is applied to keep the green phase running until the bus approaching the intersection can go through. There will be a preset maximum value for the time of extension so as not to disrupt other approaches severely. This means that the green extension is only for a bus that is fairly close to the intersection. Green extension and early green

strategies can be employed together to maximize the time for transit vehicles within the total signal phase.

Actuated transit phases are displayed only when a transit vehicle is detected at the intersection. For example, a left turn signal will operate only when there is a bus waiting to turn left in a bus-only lane. In such circumstances, transit signal faces look different from a standard green/yellow/red face to avoid confusion with the signals for general traffic.

The phase-rotation technique shuffles the order of signal phases so that transit vehicles arrive during the phase they need. For example, protected left turn phases are usually followed by the adjacent through phases. If the sensors detect a bus coming into the left turn lane that will not be able to get through the upcoming left-turn phase, the signal controller system can allow the through movement first and shift the left turn phase so that the bus will have time to get into position for its upcoming left turn. The phase-insertion technique allows the controller to insert a special priority phase within the normal traffic signal sequence. For example, a second left turn phase could be employed for an approach if there is a bus detected toward the end of through movement. Adaptive/real-time TSP strategies provide priority while simultaneously trying to optimize given performance criteria, such as person delay, transit delay, vehicle delay, or a combination. In this case, the signal timings will be adjusted based on the arrival time of the bus, thus reducing the overall impacts on other vehicles.

TSP Planning and Implementation

TSP project planning includes a number of steps that are common in technology implementation. In the first stage of project planning, the needs for TSP, stakeholders, operational requirements, locations (intersection and corridors), and alternatives need to be identified. Involvement of all stakeholders is a key for identifying the needs and ensuring buy-in of all parties. Smooth functioning between traffic operators and transit operators is critical. Roles and responsibilities of each stakeholder must be spelled out clearly. It is necessary to decide if the TSP system will be integrated into an intelligent transportation system (ITS) regional architecture or any existing or proposed AVL systems. If the implementation of the TSP system could be coordinated with any planned upgrading of signal systems, the project could be achieved more cost-effectively.

The clarity on geographical coverage of the system is important to arrive at decisions.

The project design stage requires identification of detailed data of existing systems and traffic, design and engineering for central control and communications, systems components, detailed design of intersection and onboard equipment, and optimization and preparation of signal timing plans. The data needed include traffic volumes, pedestrian volumes, speed and delay studies, and various transit operational details.

Depending on the system architecture, the central control system and communication system may need to be modified. It is essential to design and implement these before moving further. Similarly, any equipment and physical changes at intersections and on the transit vehicles also need to be completed. Microsimulation models could be employed to evaluate different strategies and alternatives.

The project implementation stage should take care of procurement, installation, and verification/validation. The operations and maintenance stage should ensure proper monitoring and management of performance, not only of the TSP system, but also the traffic itself. Detailed procedures should be established to ensure proper operation of the system. Periodic maintenance activities also need to be addressed. Evaluation of the system through detailed studies and data collection is necessary to get feedback on the performance and to make any necessary changes once the system is in place. This feedback can also be used to improve transit scheduling.

TSP System

Mature TSP systems involve the interaction of transit vehicle, transit fleet management, traffic control, and traffic control management. Vehicle detection, the priority request generator (PRG), the priority request server (PRS), and TSP control are the important functional applications of the system.

Detection systems sense an incoming vehicle and deliver data such as the location and arrival time to a device. This device is connected to the PRG, which can be located in the transit vehicle, the transit management center, the traffic management center, or the traffic signal control system that is equipped with wayside transit vehicle detection. The PRG will then request priority from the traffic control system and triage multiple requests as

necessary. The PRG is linked with the PRS through specific communication systems. The PRS is contained within the traffic control system and processes the requests for a range of TSP strategies. TSP control incorporates traffic and transit TSP functions in both the transit management and traffic control management systems.

The traffic signal control system is responsible for acting on the priority request and making any applicable changes to the signal indications via the local traffic signal controller. The interface between transit vehicles and traffic signal control systems is central to the operation of a TSP system.

The four main components of the traffic control system are the hardware, software, vehicle detection system, and communication systems. Main controller types used in the United States and Canada are electromechanical controllers, National Electrical Manufacturers Association (NEMA) controllers, Type 170 controllers, and advanced transportation controllers. The controllers might or might not come with associated software.

The vehicle detection can be achieved with hard-wired loop detection, infrared detection, sound-based detection, radio-based detection, and Global Positioning System (GPS)–based detection.

Hard-wired loop detection systems consist of a transponder attached to the underside of the transit vehicle and a vehicle detection receiver that integrates with the signal controller. The system typically consists of an infrared strobe emitter located on the transit vehicle, infrared detectors located at each intersection, and a “phase selector” interface within the traffic signal controller cabinet that relays the message to the traffic signal controller.

A sound-based detection system consists of emergency siren detectors and digital sound-wave recognition systems. Radio-based detection systems consist of radio frequency (RF) transponders mounted on the transit vehicles and RF-tag readers installed upstream of the signalized intersections for detection. There are two types of communications in a TSP system: vehicle detection communication and communication between intersections and a control center. The vehicle detection systems are described above. Typically, intersection controllers and/or the central end are interconnected by means of a physical connection consisting of fiber-optic or copper cable. Newer systems utilize



Traffic signal priority (TSP) involves optimizing signal timing to create a smooth flow of traffic along a transit route. This optimization improves service and reduces delay for mass transit vehicles at intersections controlled by traffic signals.

wireless technology, which eliminates the need for expensive conduit and cable connections between intersections and the control center.

TSP Today

More than 50 transit agencies in North America have implemented TSP systems. Though TSP was implemented as early as 1985 (Charlotte Area Transit), the majority of TSP deployments were completed in the late 1990s and after 2000. The most common bus TSP application is a system that operates in mixed traffic on four- to six-lane arterials. Some BRT systems and light rail transit (LRT) systems also employ TSP. In most places, the systems are in place on one or two corridors only.

The number of signalized intersections with TSP functionality ranges widely, from one or two intersections to more than 1,000 intersections in large metropolitan areas. The bus stop locations are a mixture of near- and far-side locations. (Near-side stops are on the approach side of the intersection while far-side stops are on the departure side of the intersection.)

A large number of agencies use NEMA controllers and associated software. The vehicle identification

systems are either optical vehicle detection systems or loop-based detection systems. The TSP systems are increasingly being employed by transit agencies. Though there is a large up-front cost associated with implementing such systems, the experience shows that the cost is worth it compared to the benefits of a reliable transit system, better functioning of regular traffic, and overall improvement in travel experience.

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See Also: Automated Traffic Control Systems; Intelligent Transportation Systems; Intersections; Traffic Control Devices; Traffic Signals; Transit Priority Measures.

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of lights that corresponds to a certain movement in the intersection.

A phase is a set of signal groups that corresponds to a certain set of movements that have the right of way during the phase's green time. These movements are chosen to proceed concurrently without conflicting with other traffic streams. A signal cycle is completed when each phase has been served once, hence the name *cycle time* (also known as cycle length). Signal-control algorithms are typically designed to optimize the traffic flow using the phase scheme, the split, and the offset settings. The phase scheme determines the signal groups that have the right of way and their corresponding order in the cycle.

A split represents a distribution of the cycle time to the individual phases; in other words, this represents the green time allocated to each phase. An offset refers to the time shift—with respect to a reference point in time—of the start of a new cycle along a sequence of intersections. Offsets have been efficiently used to achieve progression along a certain corridor by creating a "green wave" for the vehicles traveling in one direction along this corridor, to minimize the number of stops and waiting times at a number of successive intersections along the corridor.

The above-defined elements of a typical signalized intersection are maintained and operated by traffic controllers in the field. Traffic control systems differ in how they allocate the green time for each phase. Traffic controllers can be classified into three main categories: fixed-time controllers, actuated controllers, and adaptive controllers, adaptive being the most advanced.

Adaptive signal controllers can be categorized into four generations: first generation of control (1-GC), second generation of control (2-GC), third generation of control (3-GC), and artificial intelligence (AI)-based fourth generation of control (4-GC).

Based on reviewing the literature on 4-GC systems using Multi-Agent Reinforcement Learning (MARL)-based approaches, the studies are classified into three categories according to the level of interactions between the signalized intersections in a traffic network: independent MARL (including totally independent MARL and partially independent MARL), and coordinated MARL (including directly coordinated MARL and indirectly coordinated MARL).

Traffic Signals

A signalized intersection is designed to allow conflicting traffic movements to proceed efficiently and safely by separating the individual movements in time rather than in space. The basic unit of a traffic signal control system is the signal group, a set

Fixed-Time Control (Pre-Timed Control)

A fixed signal timing plan is developed off-line based on historical or anticipated traffic counts. The cycle length and splits are optimized off-line only once based on the traffic counts and then deployed. Thereafter, the duration and order of all green phases remain fixed and do not adapt to fluctuations in traffic demand. Fixed-time control is designed based on average historical counts, which do not capture the dynamics and randomness associated with real-time traffic flows in the field. Therefore pre-timed control is best suited for locations where traffic exhibits predictably uniform arrival patterns over a long period of time. In addition, pre-timed control systems are unable to respond to unpredicted events, accidents, and other disturbances that may disrupt the anticipated typical traffic-flow pattern.

Isolated Intersection Fixed-Control

In fixed-time control, the signal's cycle time is distributed over the signal phases based on historical or known-in-advance volumes. Between phase switches, start-up and clearance times are needed for drivers to clear the intersection, typically considered lost time as they are not fully used for traffic flow. Therefore, in one hour of traffic flow, shorter cycle times typically result in a higher percentage of lost times. Intersections with shorter signal cycles therefore operate at lower overall capacity levels.

On the other hand, the longer the cycle times, the longer the red phases, and hence the longer the queues and the longer waiting times at the intersection. They also cause longer waiting time for pedestrians. In addition, some approaches will drain their traffic faster than others and the remaining green times are not fully utilized, causing more time waste. Finding the balance between cycle time and intersection delay is not insurmountable. For known traffic flow rates, a formula can be derived to find an optimal cycle time and green splits of all phases such that the average delay for all vehicles is minimized. There are many such basic methods in the literature, including, by way of an example, the Webster method.

Progression-Based Fixed Control

In addition to timing individual intersections, bandwidth optimization methods use traffic volumes, signal spacing, and a desired travel speed to determine the optimal progression band that can be

achieved along a corridor. Examples of bandwidth-based methods include MAXBAND, ULTIBAND, and PASSER. On the other hand, disutility-based methods use a model to minimize the disutility of a specific measure such as intersection delay or the number of stops. These models are generally designed to first find a common cycle length that minimizes the overall delay in the system and then calculate the offset required for progression. Examples of disutility-based methods include TRANSYT and SYNCHRO.

Actuated Control

Unlike pre-timed signal control, actuated traffic signal control systems are responsive to traffic flow fluctuations. Actuated traffic control requires actuated traffic controllers and vehicle detectors placed on the approaches of the intersection. The actuated timing plan responds to traffic demand fluctuations by placing a "call" at the presence or absence of vehicles approaching or leaving the intersection, respectively. Once a call is received, the controller decides whether to extend or terminate the green phase in response to the actuation source.

Although the actuated signal control settings are responsive to the presence of actuation (or calls), they are less sensitive to the traffic demand (that is, number of vehicles) calling for the actuation. Actuated phases are allowed to extend up to a preset maximum. If traffic is heavy from all approaches, all phases max out and the signal operates in a pre-time-like fashion. Actuated control can be operated in one of two forms according to the designed phase detection: semi-actuated and fully actuated.

Semi-Actuated Control

In semi-actuated control, detectors are placed only on minor streets (callable phases). The main street movements are coded as noncallable phase(s); hence, activated for the entire split time every cycle, regardless of the traffic detection. The controllers are designed such that a permissive period is defined during which the controller unit allows the callable phases to be served upon a detection request. The callable phases are typically timed to maintain the minimum green time after which the green time could only be extended upon demand and to a maximum limit. Semi-actuated traffic control is best suited for locations where minor streets intersect with major streets.

Fully Actuated Control

Fully actuated control is similar to semi-actuated control; however, the detectors are typically placed on all traffic approaches, and phases could be skipped if no vehicular demand is detected. Fully actuated control is therefore appropriate for intersections exhibiting less predictable and high traffic volumes on all approaches.

Adaptive Signal Control

In adaptive signal control, signal timing actions and/or plans are continuously updated according to measured real-time traffic fluctuations and the number of vehicles approaching the intersection. Adaptive signal control parameters (for example, cycle length, phase split, etc.) are determined to achieve a certain objective (for example, minimize delay, minimize pollution, etc.), and then the traffic controller automatically implements these parameters in response to the real-time traffic flows.

Traffic flow is highly dependent on factors such as time, day, season, weather, and unpredictable events such as accidents, special events, work zones, and so forth. Such multidimensional variations in traffic flow patterns form a challenging task for fixed-time and actuated traffic control systems to efficiently operate signalized intersections. Adaptive Traffic Signal Control (ATSC), on the other hand, has the potential to be agile and “adapt” to traffic fluctuations and can therefore alleviate traffic congestion in comparison to the more commonly used pre-timed and actuated control systems.

ATSC can be categorized into four levels or generations according to their level of adaptation and intelligence. first generation control (1-GC) uses off-line libraries of signal timings, in which case the controller selects a signal timing plan from a pre-specified set of plans that are pre-optimized based on historical counts. Compared to 1-GC, the second and third control generations (2-GC, 3-GC) optimize in real time the timing plans but they are different in the hierarchy of control employed. Although still in the research stage and not yet implemented, fourth generation control (4-GC) is seen as the next generation of ATSC as it maintains the same advantages of 3-GC while addressing the issues faced in the development of 3-GC. The 4-GC systems employ artificial intelligence and self-learning techniques that are based on direct experience with the traffic environment.

First-Generation Control (1-GC)

In 1-GC, a library of prestored signal control plans is utilized. These plans are developed off-line on the basis of a variety of historical traffic data. 1-GC traffic-adaptive systems are often referred to as traffic-responsive signal control. Examples of 1-GC include TR2 (Traffic Responsive Control Mode 2) and UTCS-1 (Urban Traffic Control System-First Generation). 1-GC may plausibly operate under recurrent and defined traffic periods if random variations around the mean flows are not pronounced. In addition, incidents and unpredicted events are inevitable in transportation networks that cause traffic patterns to change substantially beyond the anticipated typical traffic flows and therefore cannot be efficiently handled by any precalculated and prescheduled timing plans. Furthermore, any pre-timed plans age with time as traffic flows change. Therefore, as traffic patterns change with time, the signal timing plans must be continually updated.

Second-Generation Control (2-GC)

2-GC ATSC employ simplified online optimization methods to dynamically adjust the signal timings (offsets, cycle time, and splits) by utilizing online surveillance information systems. In 2-GC, traffic progression along corridors is achieved in a centralized fashion. 2-GC systems such as Sydney Coordinated Adaptive Traffic System (SCATS) and Split Cycle Offset Optimisation Technique (SCOOT) overcome some of the 1-GC systems' drawbacks; they have some limitations:

SCOOT systems have been known to have a limited traffic-responsive behavior during rapidly changing conditions; 2-GC systems are centralized systems that suffer from the following limitations:

- They primarily depend on reliable communication networks to link intersections to a traffic management center. In addition, the central computer is a risky single point of failure.
- They are often not easily scalable to expand the size of the network.
- They are expensive due to detection requirements, communication requirements, and skilled labor requirements.
- They are relatively complex to operate, with many parameters to be adjusted by a human operator.

Third-Generation Control (3-GC)

3-GC traffic adaptive systems are generally similar to the 2-GC systems in terms of adapting to traffic fluctuations. However they differ in the following important features:

- They operate in a decentralized control system that offers several cost advantages over centralized control systems.
- Most 3-GC systems use dynamic programming (DP) techniques to model and solve the traffic signal control problem. DP is the theoretically ideal optimization technique for decentralized closed loop optimal control, and it captures the stochastic nature and dynamics of the traffic system.
- 3-GC systems continuously update the signal plans parameters to respond to real-time field measurements, which therefore abandon the conventional notions of cycle length, phase splits, and offsets. Such flexibility in the signal timing setup enables the controller to produce “acyclic” signal settings (i.e., the cycle length is variable).

Examples of 3-GC systems include OPAC, PRO-DYN, and RHODES. 3-GC systems have the following limitations:

- The unfeasibility of simultaneously handling/optimizing larger groups of intersections because of limitations in the optimization methods. DP methods require a state transition probability model for the traffic environment, which is difficult to obtain and maintain. Also, the number of states that could represent wide traffic conditions is typically massive and grows exponentially with the number of intersections in a group. Therefore, DP algorithms can be computationally intractable, which hinders network-wide application of the optimization method.
- The control logic for multiple intersections is only meant to achieve progression along a certain corridor (for example, a major artery) and not two-dimensional networks; a common limitation for 1-GC, 2-GC and 3-GC systems. In congested cities, two-dimensional networks of streets

(for example, grid networks) are saturated, which is commonly the case in congested downtown areas. Nonrecurrent congestion (for example, accidents, floods, snow, etc.) may also greatly affect traffic patterns in transportation networks. Therefore, the simple progression approach sought along arterials cannot be effectively applied to a two-dimensional gridlike complex network of intersections while capturing dynamic traffic patterns.

Fourth-Generation Control (4-GC)

The fourth generation of ATSC maintains the same advantages of 3-GC while addressing the issues that have faced the development of 3-GC. The 4-GC systems are principally built on self-learning capabilities using artificial intelligence. Control agents (computer programs) learn from direct experience with the environment (intersections and traffic flows) with reasonable computational requirements to be implemented in real time. 4-GC of traffic systems is still under continuous research and testing.

Reinforcement Learning

Reinforcement learning (RL) is an artificial intelligence technique that has shown promising potential for “self-learning.” RL not only achieves as much as DP but also requires less computation and does not need a perfect model of the environment. DP examines all the possible state-action combinations while RL learns from repeated direct interaction with the environment, sampling only the most common state-action combinations. RL methods consequently capture the stochastic variations in traffic flow without the need for models of transition probabilities of all state and action combinations. As an example, DP would examine all state-action possibilities and transitions in a game of chess, while RL acts like a player who learns from previous games, learning from experience.

The basic concept of RL is concerned with an agent (for example, signalized intersection control software) interacting with its environment (for example, traffic network) in a closed-loop system in which the agent acts as the controller of the process. The agent iteratively observes the state of the environment (for example, queue lengths), takes an action (for example, extends current phase or switches to another phase), and, accordingly, receives

a feedback reward (for example, delay reduction) for the actions taken and adjusts the policy (control law) until it converges to the optimal mapping from states to optimal actions (optimal policy or control law) that maximizes the cumulative reward (for example, total delay over time). Accumulating the maximum reward not only requires the traffic signal control agent to exploit the best experienced actions but to also explore new actions to possibly discover better actions in the future.

The interaction between the agent and the environment can be viewed as two processes performed repeatedly: a learning process and a decision-making process. In the learning process, the agent adjusts the policy by updating the value associated with each state-action pair using the immediate reward value and the value of the next states. In the decision-making process, the agent chooses its action by balancing exploration and exploitation using action selection algorithms.

MARL is an extension of RL to multiple agents (signalized intersections). The decentralized traffic signal control problem is a suitable domain for MARL because of the inherent dynamics and stochastic nature of the traffic system. The simplest way to extend RL to the MARL is to consider the local state and local action for each agent assuming a stationary environment, and that the agent's policy is the prime factor affecting the environment.

However, MARL in the traffic environment is associated with some challenging issues because the traffic environment is nonstationary since it includes multiple agents learning concurrently; that is, the effect of any agent's action on the environment depends on the actions taken by the other agents. For instance, what an agent at a given intersection should do depends on the neighboring intersections and the actions of their agents. Each agent is, therefore, faced with a moving-target learning problem because the best policy changes as the other agents' policies change, which accentuates the need for action-coordination among agents (not to be confused with the conventional offset coordination in signal synchronization).

Action-coordination can be achieved by considering the joint-state and joint-action for the other agents in the learning process. Moreover, given that all agents are acting simultaneously, the agents' choices of actions must be mutually consistent to achieve their common goal of optimizing the group

of intersections. Therefore, the agents require a coordination mechanism not only in the learning process but also in the decision making process to make the optimal decision from the possible joint actions. Unlike conventional traffic signal coordination that maximizes green bands, action-coordinated MARL approaches allow coordination in two-dimensional gridlike networks of intersections while capturing dynamic traffic patterns.

Multi-Agent Reinforcement Learning

In the independent multi-agent control, agents (at each intersection) act totally independently by considering local states, local rewards, and local actions.

Partially independent multi-agent control extends the first type by following one of two approaches. One approach is to take the presence of other agents into account and extend the state space of the agent to include the state of other agents, while the agent is maximizing its local reward only. Another approach is to consider a joint reward (global reward) or to exchange the reward with other agents. However, neither approach is meant to achieve explicit coordination between agents' actions.

Coordinated multi-agent reinforcement learning extends the previous types of control to include an explicit coordination mechanism that coordinates the actions of the individual strategies in real time. The agent is "aware" of the effect of other agents' actions in the network while all agents act simultaneously. In this case the coordination mechanism enables the agents in a group to coherently choose their actions from the optimal joint policy without contradicting each other. Two approaches are investigated in the literature under this category: In direct coordination, the agents—through direct interaction—are negotiating the action choice. Direct coordination mechanisms are inspired by social conventions, roles, and communication.

Researchers have included an explicit direct coordination between neighboring traffic lights using coordination graphs. The max-plus algorithm is used to estimate the optimal joint action by sending locally optimized messages among connected agents. However, the max-plus algorithm is computationally demanding, requiring negotiations between the agents to coordinate their actions through direct communication. Also, because the system performs under time constraints, this forces

the agents to report their current best action at any time, even if that action may be suboptimal.

Indirect Coordination Methods

These methods drive the agent to select actions that will likely result in the best response to other agents' actions. The probability of obtaining best response values is evaluated using models of the other agents. These models are estimated from observed actions taken by the other agents in the past, without direct interaction/negotiation among the agents.

MARLIN-ATSC (Multi-Agent Reinforcement Learning for Integrated Network of Adaptive Traffic Signal Controllers) implements independent, partially independent, and direct coordination, as well as indirect coordination methods in ATSC. Indirect coordination in MARLIN seems to be the most feasible for field implementation because it achieves the desired coordination without the complexity of direct coordination.

MARLIN uses a combination of MARL and game theory. Each signalized intersection (agent) "plays a game" with its adjacent intersections in its neighborhood. The agent has a number of learning modules; each corresponds to one game. At each module, the agent estimates a model of the neighboring agent's control policy. Finally, the agent computes a best response to the estimated neighbors' models and uses it to estimate state-action values and to decide the control action.

Conclusion

Although research is rapidly advancing in the ATSC area, and more specifically RL-based ATSC, abundant opportunities exist to further extend and enhance the system, for instance, by integrating public transit and pedestrians in the decision optimization process. In the present RL-based ATSC, transit vehicles are treated as normal vehicles, and pedestrians are granted the minimum time required to cross the intersection regardless of the presence of pedestrians or not and their numbers. However, it is recommended to conduct future research that explicitly takes transit vehicles and pedestrians into consideration in the optimization/control logic.

Transit signal priority (TSP) is a common practice that assigns intersection right-of-way to approaching transit vehicles. The underlying philosophy of TSP is based on giving priority to high occupancy vehicles including transit vehicles, as

such vehicles carry large numbers of travelers. Rightfully so, TSP gives priority to high occupancy vehicles. However, if a transit vehicle is not full or not behind schedule, then TSP may be counterproductive as it creates traffic delays without benefiting people throughput. Therefore, the proper integration of ATSC and TSP is a logical next step to achieve the synergy of both techniques.

Ongoing research is examining the incorporation of the number of people on a transit vehicle in the intersection state vector. Instead of maximizing the reward for each signalized intersection based on the number of vehicles on the approaches, the reward would reflect the number of people waiting, regardless of being in cars or on buses, which in essence, optimizes people throughput or people signal priority (PSP). This will, however, require automatic passenger counters on transit vehicles and wireless communication to the traffic controller to register the approaching number of passengers.

Pedestrians can be better accommodated in RL-based ATSC by including, for instance, a scramble phase if the pedestrian demand warrants such an installation. On the other extreme, minimum greens can be used only if pedestrians are present. To implement the above, a pedestrian actuation button should be modeled to receive calls from pedestrians and included as one of the parameters. Newer technologies are also emerging that count the number of pedestrians waiting to cross. With such technologies in place, priority could be assigned to pedestrians depending on pedestrian demand levels and hence optimizes PSP. If the number of vehicles approaching an intersection and their occupancy are known (or reasonably assumed) and if the number of pedestrians can also be measured, RL-based ATSC can be adjusted to optimize people throughput or minimize people's delay regardless of whether they are in automobiles, on buses, or on foot, which is arguably the ultimate objective.

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See Also: Automated Traffic Control Systems; Intersections; Traffic Control Devices; Traffic Detection Systems; Traffic Detection Technology; Traffic Information and Control Systems; Traffic Signal Priority.

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of interacting phenomena concurrently: land use and transportation infrastructure, and transportation demand and supply are only two such examples. The timescale of transportation interventions can range from the short term (for example, minutes or hours in the case of real-time incident response) to long term (for example, years or decades in the case of forecasting the traffic of a planned freeway or rail connection). Considering the size of most transportation problems, which can range from a single intersection or corridor to a city, a metropolitan area, or a region, spatial interactions also need to be considered. It becomes apparent that these interactions cannot be dealt with easily without the help of specialized tools. Furthermore, objective and factual evidence needs to be provided in order to accompany and support related investment and policy decisions. In light of the high costs of developing transportation infrastructure, accurate forecasts of their expected impacts can play a significant role in properly allocating resources.

The field of traffic simulation has emerged over the past few decades as a response to these needs. A large number of traffic simulation models and tools have been developed during this time, ranging from simplified analytical representations of individual phenomena to integrated simulation-based models that aim to capture all aspects of traffic and traveler behavior. In order to capture these various interactions and satisfy these numerous requirements, traffic simulation tools comprise a large number of models, each of which typically has several parameters that govern its behavior.

While traffic simulation has been increasingly used in all aspects of transportation planning and operations, traffic simulation models have also received criticism. George Box famously said (decades ago), "Essentially, all models are wrong, but some are useful." While this famous aphorism might seem like a negative statement, in essence it provides valuable insight into the benefits and limitations of traffic simulation.

Traffic simulation is a valuable tool that allows transportation modelers to quantify the impact of different strategies and policies in an unprecedented level of detail. Of course, there are significant caveats in the development of traffic simulation models. If the basic requirements (that is, reasonable data, reliable calibration, and validation, etc.) are not performed, there are

Traffic Simulation

Transportation planning and management is a very complex field that needs to consider a large number

considerable dangers of creating unrealistic models. Current traffic simulation models offer very powerful graphical user interfaces (often offering three-dimensional photorealistic rendering) that make challenging these results very hard.

A successful simulation project comprises three main components: (1) a traffic simulation model, (2) adequate suitable data, and (3) a proper calibration and validation of the model, prior to its application, to ensure that its output matches the real world.

In order to meet the broad needs for traffic simulation, a wide range of traffic simulation models with different properties and characteristics have been developed over the last several decades. Traffic simulation models can be classified according to multiple dimensions, such as level of granularity or fidelity with which they attempt to model traffic. Choosing the appropriate model is a fundamental decision for the success of any simulation project. Often, modelers tend to know a tool well and use it for all tasks, irrespective of its suitability, but, ideally, one should aim to use the right (level of) tool for each task.

Classification of Traffic Simulation Models

Microscopic traffic simulators (for example, AIM-SUN, CORSIM, DRACULA, MITSIMLab, Paramics, TransModeler, VISSIM) entail detailed models of driver behavior, comprising car following, gap-acceptance, lane changing, and other disaggregate behavioral models. These models operate at the individual driver level and utilize a large number of parameters. The internal clock of such models often operates at the level of a fraction of a second, meaning that decisions about the behavior of the travelers and the movement of the vehicles may take place several times per second.

Microscopic traffic simulation allows for a much higher resolution and detail in modeling (in comparison to mesoscopic and macroscopic models), and, as such, it may provide more accurate results. Naturally, this level of detail comes at a computational cost. In earlier years, this meant that microscopic traffic simulation could only be used for limited networks. However, recent advances in computing (for example, hardware developments, parallel computing, and more efficient algorithms) have made the use of microscopic simulation practical even for real-time or near-real-time applications.

Lower resolution (macroscopic or mesoscopic) simulation models usually represent traffic

dynamics in a more aggregate way and may update the vehicle position and characteristics every few seconds. Macroscopic models are well established and mature, because they have been used for several decades already. Computationally, they offer considerable advantages, and therefore they can be used to evaluate large numbers of scenarios or very large networks. Examples of macroscopic models include SATURN and METANET.

Mesoscopic traffic simulation models represent individual vehicles and advance along links consisting of a “moving” part and a “queuing” part of each link. Vehicles move in the moving part according to a speed, which depends on the prevailing conditions, usually density. Vehicles that are queuing at the downstream end of the link are advanced based on the output capacity of the segment.

Microscopic and macroscopic traffic models monopolized the traffic simulation scene for a couple of decades, until the early 1990s, when mesoscopic simulation came to prominence. The idea of mesoscopic simulation is that each vehicle is still simulated independently but, whenever possible, at a lower level of detail. For example, when vehicles are moving in an uncongested freeway, it is not necessary to track the individual lane that they are following. However, when they reach a signalized intersection they need to be assigned to lanes, so that, for example, vehicles making a right turn do not queue and block vehicles moving straight.

Emerging traffic estimation and prediction (or dynamic traffic assignment, DTA) systems, used in real-time applications for traffic estimation and prediction, are simulation-based and use mesoscopic simulation models to capture traffic dynamics (for example, academic systems such as DynaMIT, DYNASMART, DynusT, as well as commercial products such as Dynameq). Table 1 presents some of the comparative advantages and disadvantages of each of the above types of models.

Naturally, the great interest in the field of traffic simulation means that other types of traffic simulation models have also been developed that do not necessarily fall under these categories. For example, hybrid models attempt to combine the benefits of microscopic models (high accuracy) and mesoscopic/macroscopic models (low computational complexity). To achieve this, hybrid models typically operate at a more aggregate level but allow the modeling of specific areas of interest at

the microscopic level. Another field of interest is nanosimulation models, which, as their name suggests, operate at even higher levels of detail (for example, modeling driver cognition, perception, decision making, and errors in greater detail).

Calibration of Traffic Simulation Models

Traffic simulation models include a number of parameters and input data that must be calibrated to match field observations. Calibration methodologies may depend on the type of data that are considered: aggregate versus disaggregate. Disaggregate data include detailed data on the driver behavior, such as trajectory data, while aggregate data include flow counts or speeds, which are the manifestation of the behavior of multiple drivers. Disaggregate data can be used to calibrate individual models, while aggregate data can be used to calibrate the entire traffic simulator at the same time.

Another distinction is sequential versus simultaneous calibration. In sequential calibration, each model or time period may be calculated independently, while in simultaneous calibration, all models and time intervals are calculated concurrently. Sequential calibration is more practical because it corresponds to a smaller problem, with fewer parameters and fewer data to consider, whereas simultaneous estimation offers more efficient use of data, better capturing the interactions between models and time periods.

For operational, real-time traffic simulation models, calibration can be either off-line or on-line. Off-line calibration aims to develop a historical database that supports the simulation model's capacity to match average or expected traffic conditions as captured by (archived) sensor data. While the output of this process is expected to perform adequately in off-line studies, such as the evaluation of alternative traffic management strategies, daily traffic conditions are affected by a number of factors, including incidents and weather conditions.

The off-line, "average," parameters must therefore be updated dynamically to reflect the variability of traffic conditions around their expected values. The accuracy and predictive power of the traffic simulation models may thus be significantly enhanced by re-calibrating off-line parameter estimates using real-time data. The information encapsulated in the historical database (generated

off-line) can be incorporated into this online process as a priori estimates.

While off-line and online calibration have similar objectives, their formulation and solution approaches differ significantly. Off-line calibration is a global optimization step aiming to determine the mean values of the parameters and inputs, while on-line calibration adjusts the off-line values to reflect prevailing conditions. Data from prior days may be available for off-line calibration, while online calibration will generally use smaller amounts of recent, real-time data. Further, off-line calibration has no explicit computational constraints, while online calibration must be faster than real-time. Finally, off-line calibration must estimate all traffic simulation inputs and parameters, while online calibration could focus on a subset of critical parameters.

Validation of Traffic Simulation Models

The final step of a calibration process is the validation, which ensures that the calibration has been properly completed and caveats such as overfitting have been avoided. This step is as essential as the calibration itself, because it also provides a good approximation of the final quality that can be expected from the study at hand. By running the model on a data set not used for the calibration of the parameters, the modeler obtains results for the calibration targets identified during that step and even for their statistical properties.

A large number of indicators are available for the assessment of calibration and validation efforts. Each of these has different strengths and limitations, and the question of which one to use arises very often in practice. The answer to this question is usually complex and may depend on a number of aspects related to the problem at hand, the available data (and their characteristics), and many other parameters. Usually, a reasonable approach is to consider multiple indicators, thus elucidating more aspects of the model at hand and providing a more complete assessment of its performance.

The importance of choosing the appropriate indicators is key in being able to assess the performance of a model. In general, it is difficult to distinguish between "good" and "bad" indicators. However, it is useful to consider the relative advantages and disadvantages of each of them.

The purpose of using multiple statistics is that they can capture different aspects of the obtained

results. The normalized root mean square error (RMSN) and root mean square percent error (RMSPE) quantify the overall error of the calibration. These measures penalize large errors at a higher rate than small errors.

The root mean-square error (RMSE) is a measure of the deviation of a simulated variable from its actual path. The normalized mean error (MEN)

measures the mean normalized difference between simulated and observed values. The mean percent error (MPE) statistic indicates the existence of systematic under- or overestimation in the simulated measurements. Percent error measures are often preferred to their absolute error counterparts because they provide information on the magnitude of the errors relative to the average measurement.

Table 1 Advantages and disadvantages of classes of traffic simulation models

	Advantages	Disadvantages
Microscopic	• More detailed/accurate than mesoscopic/macroscopic • Ability to explicitly model details such as traffic signal strategies, road geometry • Modern microsimulators have graduated from turning-fraction type approaches to OD/path-based modeling	• Computationally expensive • More and more detailed data required • Longer time to develop, calibrate and validate model • Calibration effort is very demanding • Microscopic detail may not be necessary for online applications and contingency planning • Even though micro simulators are getting faster, mesoscopic models would always allow larger networks to be simulated, more scenarios to be modeled, longer prediction horizons
Mesoscopic	• Practical compromise between micro and macro • Combination of aggregate and disaggregate models • Actively researched, especially in the context of real-time forecasts and generation of contingency plans • Allows for longer prediction horizons than microscopic simulation (up to one to two hours)	• Not many practical, large-scale, online applications completed (however, many research/evaluation studies have been undertaken, and several are under way)
Macroscopic	• Computationally very efficient • Mature, widely deployed technology • Can be used to quickly evaluate large number of contingency plans, thus filtering available alternatives to a handful that can then be evaluated in more detail (by another system)	• Dated technology • Not very extensible without moving to mesoscopic/microscopic solutions • Mostly limited in practice to planning/off-line applications

Source: Constantinos Antoniou.

Traffic Simulation Applications

Traffic simulation has a very wide range of applications, ranging from the off-line/planning level to online/dynamic level horizons, and from short-term to longer-term applications.

Short-term forecasting (usually up to one hour into the future) may be useful for traffic management applications, while long-term forecasting (usually up to 15 to 20 years) is usually used for infrastructure planning. Clearly, the objectives of the two applications are very different, which is reflected in the data required for each application. Microscopic simulation offers the level of detail to capture the dynamics of most short-term applications, while mesoscopic (or macroscopic) models are used for the longer-term applications because they often involve larger study areas and thus are more computationally intensive. However, recent advances in computing and algorithmic developments are starting to allow microscopic models to be used in this context as well.

The increasing demand for mobility has led to congestion in multiple modes and infrastructures, but developing new infrastructure is often not feasible or cost-effective. As a result, efforts to resolve the issue are often targeted toward demand management. Traffic simulation applications in this domain focus on the user behavior (especially the response of users to information). In this case, microscopic and mesoscopic models are most commonly used.

Microscopic traffic simulation models support very detailed analysis and modeling of transportation infrastructure, traveler information, and traffic control. Therefore, they can be used as a tool for geometric design and sizing of special infrastructure elements, such as toll plazas, bridges, tunnels, and work zones. Furthermore, traffic simulation can be used to develop and evaluate effective strategies for responding to special events and emergencies in a way that minimizes their adverse effects.

Advantages and Disadvantages

Setting up a traffic simulation model requires a lot of effort and resources, which often raises the question of their popularity. There are many views on this question, but one key answer is that traffic simulation offers a practical way to study the interactions of many different phenomena in very complex problems. Furthermore, traffic simulation offers a practical way to evaluate a large number of

alternatives at reasonably low effort and cost (after the initial cost of developing the simulation model).

An important feature of traffic simulation is that it allows the detailed assessment and evaluation of infrastructure or management schemes that have not yet been implemented, thus providing insight into their expected future performance. Based on this information, it is possible to refine and prioritize the considered alternatives.

Traffic simulation also provides a practical tool that can be used to perform sensitivity analysis on the expected impacts and benefits of considered measures and initiatives, thus providing a realistic envelope of expected conditions. Based on the results of such an analysis, it is possible to proactively manage the range of outcomes of a project and thus be prepared to deal with any contingencies.

The disadvantages of traffic simulation include the high cost of developing the models, acquiring the necessary data, and calibrating the models to replicate the prevailing conditions, and, possibly, the high computational runtime. Developing a realistic model for a reasonably sized network (for example, a city) can take several months, assuming a knowledgeable team of modelers and adequate data. Similarly, once the model is ready, it may take one or more hours to run it for a single simulation (in the case of more detailed models).

Caveats

Traffic simulation is a very attractive option for transportation modelers and decision makers alike, because it provides a rigorous tool that can be used to support decision making. However, there are many situations that can undermine the use of traffic simulation.

One usual problem is the lack of clear goals at the start of the traffic simulation project implementation. Another common issue is the choice of an inappropriate level of detail (either too aggregated or too detailed). The problem of choosing an aggregate model where more detail is needed is obvious. However, the opposite can also be a problem, such as when a too-detailed model is chosen for an application that could be served by a more aggregate model. Although the development of the more detailed model requires additional resources, the introduction of a higher level of detail (and thus uncertainty) that may not be directly relevant to

the problem at hand might dilute the impact of the modeled phenomenon.

Another group of problems related to traffic simulation originates from the lack of communication and understanding between teams of engineers and decision makers regarding the use of traffic simulation. Examples of this divergence include different objectives, needs, and exploitation plans for the traffic simulation models. For example, the pressure for quick results might lead to compromise in the calibration and validation process, thus leading to unreliable results that can jeopardize the validity of the traffic simulation results.

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See Also: Microsimulation Models; Networks Modeling; Route Assignment Models; Transportation Modeling and Planning Software; Travel Model Calibration and Validation.

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Traffic Studies and Surveys

This entry discusses the surveys that inform traffic and transportation analysis models and provide basic inputs for running and calibrating these models. Apart from being a feeder mechanism for transportation models, traffic surveys provide data

for road engineering interventions and for assessing the synergies between urban-transport planning, regional, economic, environmental, and social development sectors.

Traffic studies are based on the various surveys carried out as an integral part of the entire urban-transport planning process. Traffic surveys consist of a set of surveys conducted at different scales (for example, regional, city, area, or intersection) and for different entities (for example, users, operators, municipal urban planning authorities, or road authorities) as determined by the requisite data need. Most of the traffic surveys consist of quantitative data collection techniques, which are increasingly being supplemented by qualitative data.

Traffic surveys range from preliminary reconnaissance surveys to detailed data collection surveys, and offer a holistic overview of the various parameters that dictate the traffic conditions of a given place. The most important primary traffic surveys are inventory or reconnaissance surveys, traffic-flow surveys, speed surveys, travel-time and delay surveys, origin-destination surveys, intersection-turning-movement surveys, parking-use surveys, environmental-impact surveys (for example, noise impact surveys or air quality surveys), user surveys (for example, public-transport-user surveys, cyclist surveys, or pedestrian surveys), operators surveys, household surveys (for example, socioeconomic and travel behavior surveys), stated-preference surveys, and vehicle weight surveys.

Data gathered in the primary surveys are supplemented by secondary data surveys to build out the context and development patterns of the case in question. This category of survey is called secondary-data surveys, which include road inventory and reconnaissance surveys.

Road inventory surveys are conducted to assess the physical conditions of the road network in the area being analyzed. The aim is to identify infrastructural and capacity issues (for example, bottlenecks) and also to make assessments of the latent capacity of the network for informing future development and planning processes.

Road inventory surveys are designed to shed light on the following elements:

- Existing road hierarchy
- Geometrics and cross sectional elements of the roads and intersections

- Used and spare capacity levels, level of service (LOS), and bottleneck zones
- Street infrastructure (for example, lighting, signage, street markings, and guard rails)
- A rudimentary analysis of the existing problems, potentials, and possible constraints in designing and executing traffic management plans

Traffic Flow Surveys

Traffic flow surveys are conducted to get an estimate of the number of vehicles classified by type of vehicle on a given stretch of road at a given point in time. Typically, they are conducted round the clock using smart closed-circuit television (CCTV) for an average day. Technology advancement has made it possible to obtain counting/classification and spot speed estimation as a one-batch process using cameras fitted along the major road networks. Survey data is typically processed to give an estimate of the annual average daily (AADT), hourly (AAHF) or peak hour (PHF) flows, traffic composition, and directional split.

Speed Surveys

Speed surveys or spot speed surveys provide instantaneous speeds of vehicles at the recording site. These are typically used in accident analyses and to assess both the need and impact of various traffic management measures. A few of these measures include speed limits, signal settings, road markings, speed-change lanes, no passing zones, traffic signs, and pedestrian crossings.

Travel-Time and Delay Surveys

Unlike spot speed surveys, travel-time and delay surveys are designed to provide information about speeds over a stretch of road or an entire route. The total travel time contains the journey time and the travel-time delay (that is, the difference between the actual travel time and the travel time measured under non-congested traffic conditions). The primary aims of measuring journey speed, travel time, and delay time over road-network sections are to identify the causes and locations of traffic congestion, measure the before-and-after impacts of road and traffic management improvements, provide inputs for transport planning/trip assignment/route diversion models, and facilitate the economic analysis of alternative transport improvement proposals.

Origin-Destination Surveys

Origin-destination (OD) surveys are designed to extract information on the traffic flows between the designated zones in an area. OD matrices are the building blocks of any transport demand modeling endeavour and are of paramount importance. These matrices can be further broken down to be made suitable for meso- or microsimulation purposes. OD matrices are typically created separately for different transport modes, thus usually giving three sets of OD matrices—for cars, heavy vehicles, and buses.

Intersection-Turning-Movement Surveys

Intersection-turning-movement surveys are conducted to analyze the traffic flow (including pedestrian flow) conditions for major intersections. The primary aim of the survey is to extract flow and directional split on the different arms of the intersection along with the existing delay and conflict characteristics. The results from such surveys provide input for microsimulation of the critical intersections, the results of which are used to prepare both long-term geometric improvement plans and short-term traffic management plans.

Parking-Use Surveys

Parking-use surveys, accumulation surveys, and concentration surveys are undertaken to derive an estimate of the utilization level of the public parking lots, roadside parking, designated office or special space parking, and other parking types. The occupancy data give an idea about the demand and supply characteristics, hourly variations, and the possible impacts of planned projects in the future. It is essential that survey areas and time slots (in case a 12-hour survey is not possible) are clearly defined and earmarked to gather accurate data on the accumulation levels.

Parking use surveys are also essential in making mobility management plans, which aim to shift work-related mobility patterns from cars to public-transport usage.

Environmental-Impact Surveys

Environmental-impact surveys include both noise impact and air quality surveys. The unprecedented growth of motor vehicle traffic has been one of the major causes of growing noise and air pollution in cities. Noise impact surveys and air quality surveys



Traffic surveys also include parking-use surveys in public parking lots, such as this parking structure in downtown Santa Monica, California. Determining the number of parking visitors over a designated period of time can help in planning future projects.

are undertaken to keep a record of the level of pollution and to monitor the level contingent on various factors. Some of these factors include impact analysis of new programs, seasonal variations, possible solutions for ameliorating pollution, quantifying health effects, and others. Most of data is collected through advanced automated tolls and results are analyzed in software programs such as Soundplan for air pollution calculation and AutoCAD extensions for noise pollution analysis.

User Surveys

User surveys include public-transport-user surveys, cyclist surveys, and pedestrian surveys. The objective of this kind of survey is to elicit information from the end users regarding their needs, problems, and issues, and to gauge their reactions to existing or planned policies. The heavy dominance of quantitative data collection and techniques has come under severe critique in the last two decades, which has necessitated a wider use of such surveys.

Qualitative data is now considered vital to supplement the data collected from quantitative surveys. We can trace an almost linear development from the 1950s and 1960s, with a growing interest in designing for the car, to a people-centered emphasis

on improved living conditions in the 2000s. This evolving perspective can simultaneously be traced in a shift from traffic models to a needs/accessibility-based analysis. This is manifested by modifications taking place in areas governing the core paradigm, definitions and measurement, modeling and analysis, project evaluation, and a wider acceptance and usage of user surveys.

Operators Surveys

Operators surveys are conducted to extract details related to the operation of vehicles, for example, trip characteristics in terms of OD, modal composition, operational characteristics in terms of route of operation, vehicle utilization, passenger occupancy, operating cost and revenue, and reaction to the existing policies and programs. With an increasing focus on reducing car usage and boosting public transport utilization, such surveys provide vital inputs for bettering the existing public transport supply.

Travel Behavior Surveys

Travel behavior surveys include household, socioeconomic, and travel behavior surveys. Most of the developed countries have an established protocol for running countrywide travel behavior surveys. These surveys are comprised of three major sections: socioeconomic data, access to modes and related usage data, and details of trips undertaken. The data collection format for trips varies from country to country, ranging from weekly trip diaries to daily trip diaries. The inputs from these surveys form the basis of national-, regional-, and local-level transport modeling exercises.

The following points enumerate the classic approach followed in conducting travel behavior surveys:

- Designing of draft questionnaires
- Deciding on the mode of conducting such surveys, such as phone based, Internet based, or face-to-face interview
- Appointing and training of researchers or selection of a market survey agency
- Conducting pilot surveys
- Revising the questionnaire in light of inputs gathered from the pilot survey
- Conducting the main survey
- Coding, cleansing, and checking the data
- Analyzing the data

Stated-Preference Surveys

Although revealed-preference surveys are the most popular in traffic analysis, stated-preference surveys can be used to ascertain respondents' preferences for a given hypothetical set of transport options. The options are typically descriptions of transport situations or contexts constructed by the researcher, and, by their nature, stated-preference surveys require purpose-designed and targeted surveys for collection of relevant data.

Vehicle Weight Surveys

Vehicle mass data are critical to the structural design and management of highways and bridges and are used regularly in transport planning and economic studies. Vehicle weight surveys assist in charting seasonal pavement load restrictions, which ensure optimal performance and durability of highways.

Secondary Data Surveys

The primary traffic surveys provide information on the existing traffic characteristics and, in some cases, gauge the possible effects of proposed plans and projects. The secondary surveys, on the other hand, contextualize the findings from the primary surveys through proving vital inputs like land use characteristics; demographic trends; history and culture of the place, heritage sites to be conserved; accident data and accident-prone links and junctions; other planned urban or transport projects, policies; and funding outlays, among others.

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See Also: Automobile Trips; Commuting; Traffic Psychology; Transportation Statistics and Databases; Transportation Surveys; Travel by Households; Travel by Mode; Travel by Persons; Travel Diaries; Travel Modeling; Travel Surveys.

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Traffic Variables

The study of human movement serves as a prime example of how mathematics can be used to understand almost all aspects of our lives. From an algebraic standpoint, a variable is an element that must be taken into account to solve an equation; this is true in both simple pre-algebra equations or complex models constructed to predict human behavior.

Within the realm of transportation studies, traffic variables are used as part of complex models, which are used to predict the flow and other aspects of human movement. Thus, traffic variables are those elements that are taken into consideration to predict the movement of people. Almost anything even tangentially involved with transportation can be considered a variable, and these variables can be simple (such as speed) or complex and dynamic (such as those involved in commuting or traffic jams). In addition to automotive traffic, traffic models and variables can be used to understand airplanes, trains, pedestrians, buses, and personal automobiles.

The Mathematics of Human Movement

Humans are complicated creatures. Thus, the mathematics of the social sciences can be as complex, or perhaps more complex, as the mathematics of the natural sciences. Scientists studying commuter patterns use traffic variables as part of their traffic-flow models in order to achieve goals as diverse as easing congestion during rush hours, determining where a new stop light may be needed, and predicting the impact of a new convention center on congestion in a downtown metropolitan area.

Traffic variables are quantifiable elements that the developers of traffic models are able to take into account in their efforts to predict the collective human behavior that is the movement of traffic. When used in predictive models, the following traffic variables can be used: the distance between

cars in a given track of roadway, vehicle occupancy, population density in a given area, average weather patterns in the region studied, the density traffic must reach before creating a traffic jam (also known as jam density), the frequency of traffic jams, the average speed of a set of vehicles, the cumulative vehicle arrival function over space and time, the average speed of traffic when there are no constraints on movement (also known as free-flow speed), the speed at which deaths tend to increase, driver behavior, and fatality statistics based on car year, make, and model of vehicle.

Traffic modeling is performed in an effort to predict in a consistent way how individuals will move in a given area in a consistent way. Once transportation analysts compile data that could be used as traffic variables, they may then develop traffic models. Modeling is utilized to both improve existing systems (for example, streets, rail lines, and sidewalks) and plan new systems or elements that may interact with systems (for example, a new building or park).

Case Study of a Traffic Variable: Speed Limit

Vehicle speed is one of the most intuitive and easily studied traffic variables. Maximum and minimum speed limits have the effect of putting most vehicles within a certain speed range. This remains true even if many vehicles travel slightly above the speed limit. For example, if the speed limit were 65 miles per hour (mph) and the minimum speed were 60 mph on Interstate 71 outside Cleveland, Ohio, we could reasonably expect the average vehicle to be traveling somewhere between 60 and 75 mph. Thus, in this example, variation has been minimized and the traffic variable of vehicle speed is able to be integrated into predictive travel models.

The variable of vehicle speed can be used to predict many outcomes. Among these outcomes are the likelihood of accidents and the severity of regional pollution. Studies by the American Automobile Association (AAA) have shown that the risk of severe injury or death to pedestrians in collisions between vehicles and pedestrians dramatically increases as a vehicle's speed increases.

According to AAA, collisions between pedestrians and vehicles have about a 10 percent chance of fatality if the vehicle is traveling at 15 mph, but, as one would expect, the chance of pedestrian fatality increases as speed increases. At 23 mph, there is a 25 percent chance of pedestrian fatality.

The chance of pedestrian fatality dramatically increases as vehicle speed goes beyond the typical residential speed limit of 35 mph. At 50 mph, the chance of pedestrian death is 75 percent; and when a vehicle traveling at 58 mph strikes a pedestrian, the chance of pedestrian death is 90 percent.

By studying this traffic variable of speed, AAA was able to establish a clear relationship between vehicle speed and the probability of pedestrian death in collisions between vehicles and pedestrians. These results could then be used to justify lowering speed limits in residential areas or to persuade drivers to abide by already existing limits. The traffic variable of speed can also be used as a predictor of pollution. Studies have shown that increases in speed limits may result in a corresponding increase in air pollution. This was shown by comparing air pollution levels in metropolitan areas in Spain.

Atmospheric scientists compared air pollution in cities that decreased speed limits to 80 kilometers per hour (just under 50 mph) with those that did not decrease their speed limits. The study showed that those areas in which speed limits were lowered experienced nearly 11 percent decreases in air pollution levels. In this way, scientists were able to use the traffic variable of vehicle speed to predict air pollution. Results of this study may be used to both encourage drivers to abide by lowered speed limits on an individual basis and/or encourage additional cities to lower their speed limits.

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See Also: Pedestrian Safety; Speed Laws and Enforcement; Traffic Safety and Risk Assessment; Traffic Studies and Surveys; Transportation Statistics and Databases.

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Train Stations, Economics of

Historic and abandoned railway stations, or train stations, are being identified increasingly by private and public developers for reuse and redesign projects. Rail transportation and travel has changed markedly since the birth of the railways. These changes include predominantly operating technologies and systems, and user demands and expectations. These influences have resulted in the abandonments of many original railway stations and associated building, because of the unsuitability of stations in light of technological and social progress, as well as capacity and behavioral changes and the competition from a vast road transport network and highway development. In the United Kingdom, the number of disused railway stations totals 1,825 and is rising.

The golden age of railways and the train stations that once served lines now closed, or that have been replaced by larger, more modern and efficiently designed stations, evoke a fond and emotional nostalgia within many countries, including India, the United Kingdom, and the United States. Railway stations in the United States were once edifices of community pride, representing connections to a wider world beyond town limits, and they were celebrated. Many of these buildings, designed and constructed during and after the Industrial Revolution, display a vast array of unique architectural features and components reflecting local styles of

building and local materials. Indeed, leading architects, engineers, and contractors of the day were attracted by the fame, prestige, and money involved in railway building design and construction. This has resulted in often diverse building styles, ranging from gothic to neoclassical, Moorish to art deco, and Victorian to traditional. Many of these historic railway stations, therefore, are still recognized for their architectural merit and industrial heritage.

Some are identified as important buildings for protection and preservation by such heritage organizations as the Secretary of State for England and Wales, the World Heritage Committee, and the National Register of Historic Places (NRHP) in the United States. In fact, the NRHP emerged from the historic preservation movement triggered in the 1960s by the demolition of New York's original Pennsylvania Station.

To be considered for the NRHP, a structure must exhibit age, integrity, and significance. Owners of such designated properties can take advantage of tax benefits and funding opportunities. To provide property owners with a financial incentive to rehabilitate their historical structures, tax incentives for the preservation of historic structures exist at federal, state, and local levels.

Federal, state, and local grants for urban revitalization and local bonds proceeds—along with charitable foundations, private companies, community and interest groups, philanthropists, and private individuals—are among the funding sources that have contributed to the renovation of train stations. Although these historic buildings may have become a surplus for modern railway operational requirements, the reuse, revitalization, and renovation of unused railway stations provides communities with facilities for purposes other than those originally intended.

Repurposing Old Railway Stations

In the 2009 PennDesign report on planning for America's emerging high-speed rail system, prepared for high-level officials in the Department of Transportation and Federal Railroad Administration, one of the central recommendations was the reuse of historic train stations as part of the proposed American High Speed Rail (HSR) network.

The report stated that while "new stations will be needed in some cities, the renovation and reuse of America's historic train stations should be a central

tenet of the American HSR project that will help foster community pride and renew interest in the rail transportation.” However, where train stations are no longer needed for their primary function, with good design and imagination, historic railway stations can be transformed for a variety of uses.

Examples of these uses include but are not limited to museums, shopping malls, hotels, restaurants, markets, and residences.

The Gare d’Orsay in Paris, France was saved from demolition in the 1970s by the French government giving it preservation status and converting it to what is today the Musée d’Orsay. In the United States, the Cincinnati Union Terminal, designed by New York architects Alfred Fellheimer and Stewart Wagner and dedicated in 1933, is now repurposed as the Cincinnati (Ohio) Museum Center, which houses three museums within over 500,000 square feet. Similarly, in Kansas City, Missouri, there is an ongoing project to convert the French Renaissance central rail station into a science museum.

The Estação in Curitiba, in Brazil, was built in 1883 for the Curitiba to Paranaguá line. It now boasts a sprawling mall, 10 cinemas, and four museums. A steam locomotive remains permanently stationed in the mall as a reminder of the building’s past use.

Nashville’s Romanesque Union Station, opened in 1900, was constructed of locally quarried limestone, Tennessee pink marble, carved hardwoods, stained-glass windows, and wrought iron. Today, the center-city landmark is the site of a luxury hotel. At the other end of the Nashville, Chattanooga and St. Louis Railway line is another Romanesque Union Station in St. Louis, Missouri. Originally opened in 1894 as the largest single-level passenger rail terminal in the world, the station closed in 1978, but the building now houses a shopping mall and the Hyatt Regency Hotel.

On the other end of the luxury spectrum is the colorful, rustic, and environmentally friendly hostel La Vieja Estación in Puente del Inca in Aconcagua, Argentina, which used to be the station for the Transandine rail line operating through the Andes Mountains between Chile and Argentina. It has been turned into a hostel for travelers visiting the nearby Aconcagua National Park. El Galpón in Buenos Aires, Argentina, is a marketplace for fresh, local, and organic produce and products.

The Deptford Project in London is a restored part of the station that escaped an earlier partial

demolition and is now used for restaurant facilities. In the Meon Valley in Hampshire, England, many of the now closed branch line stations are being bought by private individuals to repurpose as private accommodations or guest houses.

Train Stations Revived as Destinations

The reuse of train stations has gone beyond single-use repurposing. In Denver, Colorado, the \$900 million Union Station redevelopment is following the example of many mixed-use renovation projects that have helped revive urban centers throughout the United States. The mixed-use Union Station development, scheduled to open in summer 2014, will include the historic 1881 station building and almost 20 acres of surrounding land. In addition to hotel, retail, office, and residential development, a central feature of the project will be its multimodal transportation hub, which will bring together Amtrak regional trains, several commuter rail lines, a 1,100-foot-long underground bus depot, and a free shuttle to nearby stations of the light rail transit system.

Train stations also provide municipal office space. In Pueblo, Colorado, and Collierville, Tennessee, the old stations house the city administration. In Louisville, Kentucky, the reuse of the station was recognized by the Department of Transportation and the National Endowment for the Arts with a Design for Transportation Award for the transformation of its station into offices for the Transit Authority of River City. The repurposing involved a high level of restoration, including cleaning the stained glass and ceramic tiles and restoring the red oak staircase and paneled walls. This project also demonstrated that the perception that reuse and renovation of these buildings is disproportionately expensive in comparison to a new building is flawed. The total cost of renovation was calculated to be just three-quarters of that of a new facility.

Renovation and restoration projects involving train stations are diverse and towns and cities are capitalizing on the old buildings, not just for their intrinsic value but also for the boost they provide their communities. Historic railway stations and their associated buildings are places that are deeply rooted in the American experience, and this emotional connection leads to the pressure, desire, and availability of support from the public in protecting and repurposing them.

Not only does the reuse of historic railway stations preserve and improve the building and its architecture—as well as its heritage—for the future but it also offers economic and social benefits, which include the following:

- Construction costs are usually significantly less than new buildings because the structure and the site are already in existence, although challenges associated with new types of land use and proposed activity may arise.
- Jobs are created, not only in the renovation work, but also through the much longer-term revitalization of the surrounding area.
- Rail station developments can have wider economic development and rejuvenation effects on infrastructure and services within the adjacent area. With the transformation of old railway stations follow associated mixed office, shopping, and residential uses.
- The location of these stations is often in downtown and central areas, providing ease of access for local inhabitants, commuters, and travelers.

Nonetheless, repurposing old railway stations is a major undertaking. To preserve the rich architecture and history of these buildings requires all new electrical and mechanical systems, which must be located strategically to reduce visual intrusion on the historical aesthetics. Also, specific historic designations on these buildings may prohibit particular renovation work or structural alterations, thus precluding certain types of uses.

Conclusion

Abandoned and unused railway stations are attractive buildings for reuse. They are often located close to or on existing infrastructure networks and are proximate to services and customers. Repurposing these buildings is increasingly attractive, not only because of the grants and tax incentives that may be available, but also because of the architectural merit of these buildings. Further, they represent an attractive option for developers facing difficulties associated with new development on greenfields.

The popularity and passionate feelings toward old station buildings are beginning to resonate

beyond Western countries, too. For example, South Korea is one country where the benefits of revitalizing these buildings for other useful purposes is being recognized.

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See Also: Rail Transit Planning, U.S.; Rail Transit Planning, Worldwide; Railroad Industry, Economics of; Recreational Travel; Trains.

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Trains

Trains are a mode of transport operating on exclusive tracks typically traveling over longer distances than subway or elevated railways. Most train routes were built in the 19th century principally to provide freight transportation, which in many countries is still the case. When passenger trains began operating between freight trains to serve adjacent cities and suburban areas between them, developers

quickly saw the opportunity to build residential areas along those routes to cater to commuters.

Train Target Market

The present-day passenger train market typically targets people with personal automobiles who commute by rail into the nearby central business district (CBD), either because the journey is too long to drive in an appropriate frame of time, because roads are congested, parking in the CBD is limited, or they have made a choice in favor of a less environmentally damaging transport mode.

In the United States, the average commute time is about 40 minutes. Train commuters help raise this average by their long commute times, often over an hour. The London (United Kingdom) train commuter market stretches from Peterborough in the north to

Southampton in the south, from Folkstone in the east to Bristol in the west, up to 120 miles (190 kilometers) distant from the center of London. New York also has a large train commuter catchment, with the Long Island market stretching about 100 miles away as one of the earliest and continuously operational.

Trains also target longer-distance journeys between cities hundreds of miles apart. In the United States, the National Railroad Passenger Corporation/Amtrak serves more than 500 destinations in 46 states, the District of Columbia, and three Canadian provinces. Amtrak's busiest route is the Northeast Corridor that connects Boston, Massachusetts, with Washington, D.C., and New York City with both; it also serves Philadelphia, Pennsylvania, and Baltimore, Maryland, and several smaller cities and regional hubs. Approximately 260 million intercity



A passenger train like this one in San Mateo, California, can consist of several locomotives and coaches and may use double-decker cars to carry more passengers per train. In the United States, more than 2,200 trains traverse some portion of Amtrak's busiest route, the Northeast Corridor between Washington, D.C., and Boston, Massachusetts, every day. Amtrak's entire network serves 46 states and more than 500 destinations, carrying as many as 260 million intercity and commuter rail passengers per year.

and commuter rail passengers rely on Amtrak annually, and more than 2,200 trains operate over some portion of the Washington–Boston route every day.

With congested airspace and unpredictable weather affecting short-haul airline flights along this heavily traveled corridor, Amtrak carries triple the number of passengers between Washington, D.C., and New York City as the airline industry, and more riders than all commercial airlines combined between Boston and New York.

Whether passengers are commuters or intercity travelers, the main attraction of trains is their fast operating speed made possible by stations widely spaced and a high maximum running speed. Because the distribution of trip length is primarily short journeys, trains are aiming at a small proportion of all trips, but carry a large percentage of those trips.

Function of Railways

The exclusive use of the rail right-of-way offers a number of important advantages, not least of which is a high operating speed in an uncongested (that is, exclusive travel) environment. The second advantage is that trains operate from and between exclusive stations, where value-added functions for passenger trips can be offered, such as park-and-ride lots that make multimodal travel with cars and trains more convenient.

The ability to collect trainloads of passengers at a station improves operating economics, leading to full (or nearly full) trains for much of the length of the line. On some systems, express trains are offered end to end for a market, with stopping trains calling at a limited number of intermediate stations.

With fewer stations than a subway, train lines often have bigger stations and longer trains to provide high-capacity flows, with fewer trains in use. Longer trains also allow in-transit passenger services, such as meals and refreshments, a value-added service and a further attraction for train use.

New Railways

With existing rights-of-way and an infrastructure of rail routes, a railway has the potential to be enhanced in economical ways. However, where a new railway is proposed to be built, the costs increase by at least one order of magnitude. Among other additional obstacles, they may face community opposition if the land for a new right-of-way is purchased compulsorily.

In order to justify this much bigger capital cost, the operating benefits must be substantial. Ideally, passenger numbers and revenue should more than cover operating costs, leaving a surplus to retire some of the capital debt. If this ideal is not possible, the project falls back on cost-benefit analysis, where non-revenue aspects—such as congestion reduction, pollution mitigation and other reductions in environmental impact, passenger (that is, worker) time savings, more mobility options for people without personal cars (often low-income and/or disabled), and potential reductions in automobile traffic crash deaths and injuries—are added to financial considerations.

Unfortunately, the value of these non-revenue items is more subjective than dollars-and-cents return on investment (ROI). In many UK cost-benefit transport analyses, passenger travel time savings is the most highly considered among the benefits. Often, these savings are merely a few minutes. Moreover, where journey times are themselves variable, planners and agencies ask whether travelers will choose a non-auto mode based on minutes saved and, if they do, whether that time is put to any useful use.

One location option for new rail line rights-of-way could be the median of existing freeways, which could be both more economical and less contentious. Bus use of high-occupancy vehicle (HOV-lanes) on freeways rarely attracts more than 10 percent of existing commuters, therefore not providing a significant increase in overall usage.

On the other hand, the equivalent lane space in the median for rail use would provide a significant increase in capacity, with research showing trains often nearly double the flow of passengers versus personal cars at peak times. Furthermore, rail lines are proven to get commuters out of their cars, not just reducing car vehicle flows and peak congestion, but also leading to an overall speeding up of journeys, not to mention environmental benefits.

Whether a new rail line uses a new right-of-way or a freeway median, the choice of station location is critical to the success of the line. Such success is often determined by the park-and-ride capacity of the lots of stations along the route.

Freeway Relief

Virtually all major cities suffer from the same traffic characteristics, namely, a very high morning

and evening peak, causing congestion, with excessive pollution emission, and spare road capacity at other times. In terms of land use, private automobile trips are the least efficient way to move around large built-up areas, not only because of the land required for the roads and junctions, but also for parking at the destination of the commute trip. This is particularly acute when the CBD is a major work destination; maintaining an efficient density of economic activity is difficult when auto parking has to be accommodated, even in multilevel structures or basement parking under high-rise buildings.

A train track takes up as much space as a freeway lane but can carry 10 times the passenger flow. When planning new rail lines, therefore, a freeway alignment can be an excellent option for the following reasons: following proven high demand, making better use of the land, increasing the passenger capacity of the freeway, reducing the congestion and pollution from car traffic, and being socially acceptable.

There are examples of freeways being taken out of service, usually as a result of some kind of emergency. One of these was the Embarcadero Freeway in San Francisco, which was a double-deck structure. A major earthquake in 1989 collapsed part of the upper deck onto the lower, killing a number of drivers. By the time the city was in a position to do something, traffic in the area had adjusted to the reduced capacity and traffic continued to flow without gridlock. The freeway was demolished in 1991 and adjacent property prices rose by over 100 percent. The space was reused for residences, a parkway, and a streetcar line, greatly improving the local environment and turning what had been an undesirable part of the city into an attractive area.

Obviously, the introduction of a new rail line with more capacity than the freeway along which it is located increases the options of the future use of the land occupied by the freeway.

Modal Split

The key to planning, funding, and improving or building rail lines is that car commuters will switch to rail. Rail opponents always claim that their city is unique and the car commuters are wedded to the steering wheel. Even if large scale market research is undertaken, people are very poor at predicting changes of their behavior in the absence of a real alternative choice. Two options are then available to rail planners; faith—or looking at other cities with improved

or new rail lines and extrapolating that experience to their unique home city. Faith is an unpredictable to determine the way people will react to a new development, and there are many examples, often demolished, of developments that failed to attract users and could not be justified economically.

Modeling mode split is now an exact science, based upon the probability of one mode of transport being chosen over another. For large groups (for example, a suburban neighborhood), this probability translates into the proportion of all trips made by auto that will be attracted to rail. The key to that modeling is the accurate representation of the characteristics of each mode, as viewed by users, in terms of travel time, reliability, and cost.

Historically, data to calibrate modal-split models were collected manually and transferred to computer for analysis. Today, cell phone origin-destination (OD) data, based on departure and arrival zones, offers orders of magnitude more data, and potentially outputs of a much higher level of accuracy than is possible from traditional manual sample surveys.

The advantage of modeling mode choice is that it allows sensitivity analyses to be undertaken to examine the outcomes of “what if” scenarios. What if gas jumped to \$20 a gallon, what if toxic auto air pollution worsened and large areas were made car-free as a public health measure? These different scenarios are quick to analyze and allow the planners to focus on one or two likely scenarios to see how best the railway can serve the community.

This focusing should include the location of rail stations, not only to maximize the catchment of the target car-commuting households, but also to best serve the most frequently used destinations. This also allows an assessment of the optimum location and size for park-and-ride stations. Such an assessment will include capturing inbound trips from outside the metropolitan area and the most attractive combination of parking and rail charges.

Part of the modal-split assessment will be the comfort and convenience of interchange to rail. The Skokie Swift (Yellow) Line in northern Chicago is a practical example of starting a rail line with a modest expenditure, and as increasing auto commute trips were attracted, the trains and stations have been enhanced. Right from the start, Skokie Swift offered 34 miles per hour (mph) transit, faster than was possible by driving parallel roads.

Almost every city can find an example where a low-cost starter rail line can be enhanced incrementally as traffic increases, so that there is at least a positive cost-benefit return, even if there is not a hard financial return. Either way, this makes better use of public money.

Sustainability

Sustainability has two major strands: environmental and financial. All too often environmentalists believe the rail system will be environmentally benign, making things no worse and ideally beneficial by reducing emission of toxic pollution and carbon dioxide, as well as reducing traffic noise.

Within this argument, rail systems, whether powered electrically or by diesel engines, will produce pollution. With electric power, the pollution is remote from the urban area and could be produced from renewable sources (for example, hydroelectricity). The amount of pollution released in the construction of power generation and a new rail line is trivial compared to car emissions. Even operational pollution is relatively small because of the high overall efficiency of the electricity cycle, with about 30 percent of input energy being converted to useful work in carrying passengers on trains, which themselves are an order of magnitude

less energy-dependent than rubber tires with much higher rolling resistance.

For diesel trains, this equation is not so clear-cut. First, diesel engines are heavy polluters, especially of particulate matter. Second, the pollution is released along the rail corridor and at stations, therefore exposing passengers and residents. Third, no matter how carefully diesel trains are fueled, there will be leakages from trains in motion and at fueling points that can pollute groundwater. Offset against this, there are now many programs to produce diesel fuel from biomass, and, therefore, to be more sustainable. Nevertheless, the energy efficiency of the diesel engine cycle is only about 20 percent.

Development Stimulus

There is little doubt that an improved or new rail line can be a major stimulant to urban development. This results from both push and pull factors. The “push” factors center around the improved accessibility that areas with rail services enjoy and the increased capacity for moving people economically and quickly. The “pull” relates to the increase in land values resulting from improved accessibility to “central places.” Such increases in land values make the intensification of development density financially viable and practical. More people can



India has one of the largest rail networks in the world but does not have high-speed rail lines capable of supporting speeds of 200 kilometers per hour, or km/h (124 miles per hour [mph]) or more. Proposals for high-speed corridors operating at 300 km/h (186 mph) on elevated tracks have not yet been implemented. The fastest train in India is the Bhopal Shatabdi, with a top speed of 160 km/h (99 mph).

live/work/shop in a given area because extra transport capacity is available and acceptable.

The pioneering study of this effect was made after the Yonge Street subway opened in Toronto in 1954. This showed a consolidation of small building lots into larger, and then the replacement of low-rise by high-rise buildings clustered around subway stations. This is exactly what central-place theory predicts. Further, this intensification of land use and the resulting rise in property values was an order of magnitude larger than the public investment in constructing the subway. Subsequent extensions of the Toronto subway have replicated this.

Studies in Boston, Los Angeles, New York, Philadelphia, Portland, San Diego, the San Francisco Bay Area, and Washington, D.C., showed positive correlations between rail transit opening or improvement and the value of adjacent commercial and residential property. This has also been replicated in cities in other countries.

Various proposals have been made for “value recapture” taxes, where the public gets back part of the rise in property values to cover some of the public investment in rail that made it possible. Normal urban property taxes are a crude and not very effective basis for recapturing public investment, because they depend on the regular revaluing of property—not usually an election winner. The other direct way in which public investment can be recaptured is by the rail authority buying land at station sites, which can be used for building the rail line and the stations. The remaining spare land can then be developed, as well as air rights for residential, commercial, or retail activities, depending on the station location.

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See Also: Commuter Rail; Commuting; Heavy Rail Transit; High Speed Rail, Policy and Planning of; National Railroad Passenger Corporation/Amtrak; Park-and-Ride/Kiss-and-Ride Lots; Railroad Industry, Economics of; Railroads, Passenger; Transit Industry Economics of.

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Tramways

There is little difference, historically, between tramways in Europe and streetcar systems in North America. They both followed similar development paths and heavily influenced one another. Initially, tramways were built to make horse traction more efficient. On the dirt roads of the 19th century, two horses could pull a maximum of 20 passengers in a bus, but 50 in a tram running on smooth rails. At that time, tramways provided transport for middle-income people and the poor walked everywhere.

What changed the characteristics of the tramway was the advent of electrification, which allowed bigger trams to carry 100 passengers, still with a crew of two, and to operate faster services, reducing unit operating costs and, therefore, the fare charged.

Probably the biggest difference between Europe and North America is that most tramways were taken into public ownership in Europe at the beginning of the 20th century, while in North America many streetcar systems remained privately owned and operated until the middle of the century. In Europe, many tramways were operated as part of the social policy of city councils to enable poor people to travel, and the availability of tramways enabled city-center slum dwellings to be replaced by suburban public housing. Tramways being run as departments of the city council usually meant that no financial depreciation was made, and maintenance was often neglected to the point where total replacement was required.

At this point, tramways were often closed and replaced by cheaper buses. The argument was that

roads were already being maintained, so they might as well be used by buses.

This experience was common in the United Kingdom (UK), Denmark, France, Ireland, Italy, Spain, and Sweden. Unfortunately, the tram passengers did not all switch to replacement buses, and, in most places, bus patronage was less than 70 percent of what it was on the clanking and slow trams.

Popularity Versus Bus Transit

In the developed countries of the Organisation for Economic Co-operation and Development (OECD), the main means of personal travel is now the private motor car. Public transit, of which tramways are part, is a minor carrier, with notable exceptions.

The city of Freiburg in Germany began an environmentally sustainable policy for transport in 1990. Since then, car use has declined to less than one-third (32 percent) of all trips, while transit has increased to 20 percent, which compares with an average of 3 percent for cities in the United States with a similar population.

How have such increases in transit in Europe been achieved? The answer lies in auto commuters' perception of transit. In most European cities, buses are the only form of transit, and buses are not viewed as an acceptable alternative to private car use. In contrast, car commuters are more willing to switch trips to rail, and tramways are perceived to be a rail service.

Germany, in particular, retained trams long after other European countries had scrapped theirs. Today, there are 85 tramways operating in Germany, nearly as many as the rest of Europe put together. German cities are both expanding their tramway networks and improving services, so that many lines are hybrids of classic tramways and modern light rail systems. Freiburg is a good example of the impact of modest but consistent investments in improving and extending tramways leading to an attraction away from car trips.

Nottingham in the UK reopened its (first) tramline in 2004 and is now constructing a second line. Since 2004, transit use has increased to 20 percent of all city trips. Both tram lines serve park-and-ride stations in the suburbs, part of the city's policy to divert car trips to transit. The experience of attracting trips from cars to trams has been repeated for all the UK and French tramways built since 1985. Typically, between 25 percent and 35 percent of tramway

passengers left their car at home or at a park-and-ride station.

Operational Requirements

The ideal rail system for an urban area might be considered a subway, or metro. However, the high cost of construction limits the number of lines that can be built. Tramways can provide 90 percent of the benefit of subways at 10 percent of the capital costs, because routes are normally built in existing city streets.

To maximize the utility of an investment in tramways, passengers must feel they will travel more quickly in a tram than by road. To ensure that experience, tramcars need traffic management that favors them, such as the provision of exclusive lanes and priority at traffic signals. These will also reduce power consumption by reducing the stops and starts tram must make (aside from stops for passengers to embark or exit).

Tram stops are located where patronage can be generated, such as residential areas and park-and-ride stations, or attracted, such as hospitals, universities, shopping centers, and the central business district (CBD). This has been the model for all European tramways built since 1985 and often results in tramways with small networks carrying more passengers than buses.

Although construction of a new tram line costs more than putting buses onto the streets, their operating costs can be covered by fares, which is not always the case with other modes. For example, in Nantes, France, within two years of opening tram line One, transit ridership had increased by 30 percent, with trams carrying 18 percent of all transit trips.

By 2007, three tram lines in Nantes were carrying 20 percent more passengers than the original bus network. As importantly, although tram operating costs are 40 percent higher than buses per mile run, trams generate over 12 percent more revenue than operating costs, whereas buses barely cover half their operating costs. So trams, in fact, are subsidizing bus services.

Impact on Urban Development

Like rail services, tramways have a positive impact on urban development. A good case study is Sheffield, England, where an out-of-town U.S.-style shopping mall called Meadowhall with 10,000 parking spaces was opened in 1990. Quickly, this

decimated city-center shopping, leaving closed and boarded-up shops in the CBD.

In 1994, a tramway opened between Meadowhall and the CBD. The Meadowhall tram stop was part of an intermodal interchange with a regional rail station, and the local bus service station also located there. Soon, a reverse in traffic flow was observed, with shoppers driving to Meadowhall, doing some shopping, and then getting on a tram to the CBD. That has resulted in the rebirth of the CBD with small, independent, and specialist shops, restaurants, and other facilities.

Modal Share

Trams get people out of cars, either all the way or for some trips. This modal switch explains why cities with trams enjoy a higher proportion of trips by transit than those that are dependent on buses. The policy implications of this are large, because many cities have erroneously operated under the belief that busways provide tramway services at minimal costs. The premise, though, is that busways will lure enough people from their cars to justify the service.

The first major busway development was in 1967 when Runcorn New Town was built in the United Kingdom, with all development clustered around a busway designed as a figure-eight network with the town center at the cross. The plan was based on the assumption that 50 percent of all trips in Runcorn would be by bus.

Even though the freeway system was built outside the town, where car trips would take longer than bus trips, the highest modal share the buses ever achieved, in the mid-1980s, was 15 percent. Today, it is only about 5 percent. When doing their analysis, planners in Runcorn failed to identify that people with cars have the ability to make local travel choices; if the alternative they are given is a bus, the car is preferred in the majority of cases. Therefore, if cities are serious about getting people to make fewer trips by car, one way to achieve this is by building and developing a tramway network.

Interchanges

Tramways are rather modest infrastructure developments, carrying potentially fewer passengers than a subway but more than a bus route. Interchanges, then, will be commensurate with that capacity. The most basic interchange is a pedestrian- and perhaps

cyclist-access tram stop that in most countries must be fully accessible for passengers with physical disabilities, requiring a platform, signage, and shelter.

The next level will be interchange with park-and-ride (P+R). As an example of the scale, the Nottingham tramway has five P+R stops, from which 5,000 trips per day are generated, 20 percent of total daily ridership. So a P+R stop will be scaled differently from a normal tram stop.

The most complex interchanges will be with other tram lines and rail lines. These may be at grade, and, if so, it should be possible to arrange the interchange at the same platform or perhaps a cross-platform interchange. If grade separation is involved, a convenient route between platforms on different levels will be needed, including elevators for those with mobility impairments or in wheelchairs. Larger numbers of passengers will also be involved in interchanging, so wider platforms and access ways are required to make movements between modes smooth and safe.

Network Structure and Service Quality

Historically, tramways were structured with routes serving many passengers to many destinations, but sharing sections of a common network. Today, the structure is usually fewer passengers to fewer routes, but run at a high frequency (for example, under five minutes), with convenient and coordinated interchanges. This allows passengers to enjoy “many-to-many” routing options for the heaviest flows, with a high-frequency walk-up-and-go service.

Service is more than the mechanics of having trams turning up on time. It also includes presentation. Tram stops that are clean and maintained will be more attractive than ones with litter and peeling paint. The same applies to the trams. They need to be externally cleaned every day and regularly repainted externally to give a showroom finish.

A simple route network is easy to operate and, therefore, easier in theory to maintain a highly reliable service. When people have the alternative of a car, a tramway that is not operating with clockwork reliability will soon lose its passengers.

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See Also: Aerial Tramways; Light Rail Transit; Park-and-Ride/Kiss-and-Ride Lots; Rail Transit Planning,

Worldwide; Railroad Grade Crossings; Streetcars/Trolleys; Traffic Signal Priority.

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Transit Centers

Historically, discussions involving "mass transit" might involve air travel, heavy rail, light rail, buses, bicycling, walking, and carpooling, but each of these modes of transportation—and the locations where one was able to begin a journey using it—were considered separately and independently. For a variety of reasons, planning and policy considerations have coalesced to create new interest in transit centers serving multiple purposes and combining several modes of transportation. These centers are becoming an exciting way to expand economic opportunities while also encouraging sustainable behavior.

While some municipalities have chosen to integrate their light rail systems with pedestrian urban malls, others have elected to downplay this connection and instead to utilize abandoned railroad rights-of-way in an effort to cut costs. As a result, transit centers represent both a bold new way of combining multiple modes of transportation in an effort to revitalize neighborhoods and to drive economic development or an endeavor to minimize terminal costs and the havoc construction and rebuilding often cause.

Background

Beginning in the 19th century, greater thought and planning began to be placed into the design and location of terminus sites for travel by rail, ship, carriage, or other modes of travel. For the better part of a century, civic pride and commercial success resulted in ever larger railway stations, bus depots, and other edifices to modern transportation.

After World War II, however, the growth in popularity of travel by automobile and airplane had an effect on centers for other modes of travel. For much of the latter half of the 20th century, mass transit, while not ignored, was not the focus of most urban developers or transit planners. As the 21st century dawned, however, a new generation began to explore how intermodal transit centers could both support sustainable practices and drive economic development.

Cities and other urban centers represent an accumulation of resources and a concentration of activity. Both of these are represented and supported by the transportation systems present in the area. In many ways, transportation systems offer the most opportunities where the greatest gathering of resources and activities takes place. This, in turn, can cause problems.

Many transportation terminals—such as ports, railway stations, bus depots, and airports—are located within urban areas. As a result, traffic congestion, parking shortages, longer commutes, environmental degradation, health risks, polluting land usage, and logistical delays often occur in or near these places. As policy makers and planners have examined these events, many have determined that automobile dependence is a primary cause of many of these. As a result, ways to diminish reliance on the automobile have been reviewed and considered as one way of reducing these problems.

Automobile travel became popular for a variety of reasons. Some of these are individual, such as convenience and consumer choice. Others, however, have been societal, such as the decision to underprice the cost of automobile travel through subsidies to roads and freeways. Communities that want to decrease their reliance on the automobile may take a variety of steps in that direction, including dissuading drivers through speed bumps or parking restrictions, prohibiting motor vehicles at certain times of the day, or enacting tolls for use of the roads.

Transit centers have come to be viewed as an additional way in which congestion, pollution, and gridlock can be addressed. Featuring more than one mode of transportation, transit centers attempt to combine the benefits of more solitary modes of traveling—such as bicycling, driving, or walking—with a mass transit experience.

The combined experience eliminates some of the disadvantages of each, because taking an automobile two miles to catch a 25-mile commute by train makes the process more convenient than either automobile or rail alone. While location plays a large role in an individual's decision whether to use intermodal transportation, planning and policy decisions can also greatly affect the attractiveness of a given choice.

Urban or suburban locations located near major transit centers, whether railway stations, subway stops, bus routes, or the like, benefit in increased land values as a result of this proximity. Mass transit systems, however, require a certain degree of population density in order to be successful. Certain past decisions on the part of transit organizations, such as charging a flat fee for travel, made the fare structure simpler, but also worked to discourage shorter trips for which mass transit is ideal. For intermodal transit to work effectively, all aspects of a system must be considered and changed if necessary.

Encouraging Intermodal Transportation

Appropriately designed and strategically placed transit centers are an ideal way of encouraging intermodal transportation. Transit centers are helpful in combining two or more modes of transportation in ways that combine the strengths of various commuting choices for travelers while also offsetting their weaknesses.

In many urban areas, the decision to develop transit centers that encourage intermodal transportation is to reduce the reliance on automobile travel while simultaneously encouraging the use of mass transit, bicycling, jogging, or walking. As progress, not perfection, is the goal of transit centers, accepting a certain level of dependence upon the automobile is acceptable, as is the idea of offering incentives to make mass transit more popular.

Many policy makers have accepted that most travel has always been intermodal. The trick is to convince commuters that it is their benefit to combine one type of rapid transit, be it rail or bus, with

other options, such as bicycling, driving, walking, or the like.

In an effort to encourage rail travel, for example, many policy makers combine incentive parking, sometimes known as park-and-ride, with bus or rail systems in an effort to get commuters to take mass transit. Incentive parking permits commuters the convenience of driving their automobiles on the initial and final legs of their commutes, while enjoying the benefits of mass transit for much of the journey.

Incentive parking, which is often offered at no or low cost, is seen as luring those who might not otherwise take public transit into the system. Critics of incentive parking, however, suggest that such schemes do little to reduce on-road traffic over time but do create entitlement programs that chiefly benefit the well-to-do. Some communities have experimented with bike-and-ride programs that encourage commuters to ride a bicycle to a transit center and then to take mass transit to reach a more distant destination. Bike parking takes up considerably less space than that for automobiles, yet such a system is impractical in many areas because of inclement weather during much of the year.

Other communities have attempted to funnel riders onto rail or high-speed buses through offering convenient feeder buses that transport commuters the last few miles at either end of a trip. Feeder buses work best when they are scheduled to arrive shortly before or after the arrival of the next leg of the commute and do so in a timely manner. When successful, feeder buses inspire rider loyalty, while also increasing revenues for the transportation system. In some areas, one company, such as a rail provider, will pay another, usually a bus operator, to provide this service because it can greatly improve the profitability of both carriers.

Some enticements to encourage those who might not otherwise consider using mass transit are quite inexpensive for carriers. For example, many metropolitan bus lines, especially those in warmer climates, now provide free bicycle carriers on the front of their vehicles. Such devices encourage those who would not otherwise consider taking a bus to their destination but will if permitted to bring the bicycle with them.

A similar situation involves trains or ferries that permit drivers to drive their automobiles onto the larger vehicle. Such an arrangement permits the

travelers to enjoy the use of their automobile once at their final destination and encourages use of lower-mileage routes, which saves fossil fuel and reduces road congestion. Again, some criticize such endeavors because they assist those who would otherwise be able to afford other options.

Intermodal Passenger Transit Centers

Transit centers work best when a variety of modes of transportation are available to commuters. For that reason, intermodal passenger transit centers appear most frequently in large urban areas that offer a variety of forms of transportation, such as heavy rail, light rail, bus, and others. Although highly popular, for example, fewer than 200 communities globally have subway systems in place. This scarcity is in part because of the great investment initially required to build such a system, as well as the necessity that there exist adequate ridership to make such an investment practical. In those large urban areas that have developed transit centers, use has often been made of extant terminals that operated previously as part of a preexisting transit system.

The Chicago Transit Authority (CTA) is one of the largest transportation providers globally, operating surface rail, a subway, and buses. It has transformed its Jefferson Park Station into the Jefferson Park Transit Center to take advantage of a variety of transit options available to commuters. In addition to the CTA's own Blue Line rail service, the Jefferson Park Transit Center offers stops for the Union Pacific/Northwest commuter rail offered by Metra (the commuter rail agency serving Cook, DuPage, Will, Lake, Kane, and McHenry counties in the Chicago area), CTA buses, and Pace (the suburban service) buses, as well as providing parking spaces for automobiles and bicycles. As a result, the Jefferson Park Transit Center serves over 2 million passengers a year, with ridership growing by over 5 percent per year.

In addition to providing access to a variety of transportation offerings, some transit centers are designed to include amenities and services that will attract potential riders, such as coffee shops, retail venues, bars, and other services that attract the busy commuter. While such offerings in and of themselves will seldom be enough to affect a user's decision to use a transit center regularly, they do work to assist those with other obligations to feel comfortable about their transportation choices. Ultimately,

transit centers work if the connections between lines are speedy, convenient, and within proximity of the traveler's home or destination. Amenities and services, however, can help inspire loyalty.

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See Also: Airport Transit Connections; Bicycle Facilities; Interstate Highway System; Transit-Oriented Development.

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Transit Corridor Planning

Signed into law on July 6, 2012, by President Barack Obama, the federal Moving Ahead for Progress in the 21st Century (MAP-21) Act sets requirements for transit corridor planning in the United States.

In Section 5309, funds are authorized for Fixed Guideway Capital Investment Grants, also called New Starts, which apply to rail transit in all forms (for example, regional rail, commuter rail, light rail, streetcars, single-rail transport (that is, monorails), and transit that operates on a separate right-of-way exclusively for public transportation (for example, bus rapid transit and ferry systems). The program provides grants for new and expanded rail, bus rapid transit, and ferry systems that reflect local priorities to improve transportation options in key transit corridors.

This program defines a new category of eligible projects, known as core capacity projects, which



In 2012, the New York City subway completed over 1.65 billion passenger trips. The MAP-21 Act authorizes funds for new and expanded transit systems in other U.S. cities to help increase mobility, reduce congestion, and improve air quality.

expand capacity by at least 10 percent in existing fixed guideway transit corridors that are at or above capacity today, or are expected to be at or above capacity within five years. The program also includes provisions for streamlining aspects of the New Starts process to increase efficiency and reduce the time required to meet critical milestones.

The Federal Transit Administration (FTA) discretionary New Starts program is the federal government's primary financial resource for supporting locally planned, implemented, and operated transit guideway capital investments. From heavy to light rail, from commuter rail to bus rapid transit systems, these public transit investments have improved the mobility of millions of Americans, helped reduce congestion and improve air quality in the areas they serve, and fostered the development of viable, safer, and more livable communities.

Fixed Guideway Capital Investment Grants

State and local government agencies, including transit agencies, are eligible for this FTA program. MAP-21 modified the Capital Investment Program by expanding the eligibility to Core Capacity Improvement projects and streamlining the project development process. New Starts projects are defined as projects with a total capital cost of \$250 million or greater or

that are seeking \$75 million or more in section 5309 funding. Eligible projects are new fixed guideway systems, such as rapid rail (heavy rail), commuter rail, light rail, hybrid rail, trolleybus (using overhead catenary), cable car, passenger ferries, and bus rapid transit, or an extension of any of these systems.

Small Starts projects are defined as projects with a total capital cost less than \$250 million and that are seeking less than \$75 million in section 5309 funding. Eligible purposes for the Small Starts program are those mentioned for the New Starts program, as well as corridor-based bus systems that do not operate on a separated right of way but include features that emulate the services provided by fixed guideway systems, including defined stations, traffic signal priority for public transit vehicles, and short headway bidirectional services for a substantial part of weekdays and weekend days.

MAP-21 also makes Core Capacity Improvement projects eligible for section 5309 funding. These are substantial corridor-based investments in existing fixed guideway systems that are at capacity today or will be in five years. A Core Capacity Improvement project must increase the capacity of the existing fixed guideway system in the transit corridor by at least 10 percent.

MAP-21 reduces the number of steps in the process for projects pursuing capital investment program funding. For New Starts and Core Capacity Improvement projects, the steps in the process consist of project development, engineering, and construction. For Small Starts projects, the steps in the process consist of project development and construction. Alternatives analysis no longer is required.

The FTA must evaluate and rate projects seeking section 5309 funding according to statutorily defined criteria at various steps in the process. The FTA is responsible for implementing changes under MAP-21 to improve the efficiency of the New Starts and Small Starts processes, and implementing the new Core Capacity Improvement process through rule-making and policy guidance, which will be developed through a notice and comment process.

Project Development Process

Under MAP-21, the new Project Development Process achieves the following:

- Eliminates the alternatives analysis requirement and instead relies on the

review of alternatives performed during the metropolitan planning and environmental review processes

- Creates the Project Development phase during which the environmental review is completed; project sponsors must complete this phase within two years or seek an extension from the FTA
- Reduces the number of FTA approval steps by consolidating Preliminary Engineering and Final Design into a single engineering step
- Requires the FTA to develop an expedited review process for determining the technical capacity of project sponsors to undertake the proposed project if they have recently and successfully completed at least one other new fixed guideway or core capacity project

Under New Starts, the Project Development phase requires a complete environmental review process, including developing and reviewing alternatives, selecting locally preferred alternatives (LPA), and adopting it into a fiscally constrained long-range transportation plan.

Under Small Projects, the Project Development phase entails the following:

- Complete environmental review process including developing and reviewing alternatives, selecting LPA, and adopting it into fiscally constrained long-range transportation plan
- Gain commitments for all non-5309 funding
- Complete sufficient engineering and design

There are two key phases in transit corridor planning in the project development process for projects seeking New Starts funding: Alternatives Analysis (AA) and Preliminary Engineering (PE).

Alternatives Analysis

An AA is a transit corridor planning study in which one or more of the alternatives under study is, or includes, a fixed guideway facility. It has as its basis the New Starts planning provisions contained in federal legislation. AA is synonymous with multimodal corridor planning, consistent with the principles

of both the Major Investment Study (MIS) process practiced in many areas around the country and the Draft Environmental Impact Statement (DEIS) required by the National Environmental Policy Act of 1969 (NEPA). Regardless of what the study is called, its intent is the same: to identify and compare the costs, benefits, and impacts of a range of transportation alternatives as a means of providing local decision makers with the information necessary to implement the most appropriate transportation solutions in priority transit corridors.

AA can be viewed as a bridge between systems planning at a metropolitan scale, which identifies regional travel patterns and transit corridors in need of improvements, and Preliminary Engineering, where a project's design is refined sufficiently to incorporate the avoidance, minimization, and mitigations necessary to complete the environmental process. AA is the process designed to facilitate the reaching of a broad consensus on exactly what type of improvement(s) best meet locally defined goals and objectives for a specified transit corridor.

Because it involves specialized technical analyses and an evaluation of transportation alternatives that have varied effects on the surrounding community, the AA is necessarily a collaborative process. The AA study typically involves local transportation planning agencies (including the metropolitan planning organization) and service providers, local governments, state and federal resource agencies, potential funding partners, and the general public, through a formal citizen participation process.

There are a multitude of ways that an AA can be coordinated with the environmental review required by NEPA. NEPA itself mandates that the EIS reflect an analysis of all reasonable alternatives, so the careful coordination of the AAA and NEPA review is essential to the efficiency of the study and to public and interagency understanding of the process.

Various coordination methods have been used, such as "incorporation by reference" to carry the AA results into a NEPA document or use of a first-tier or programmatic EIS as an AA. While the decision to conduct the AA either within or outside the NEPA process is an important milestone, which should be agreed upon as early as possible within the study process, the FTA emphasizes that the appropriate level of analysis is a function of the complexity of the transit corridor and its transportation needs, not of the regulatory framework. The level of analysis

should be commensurate with the planning decision at hand; that is, the analysis of every issue should be carried just far enough to make an intelligent selection of a preferred transportation design concept and scope from the alternatives available.

Preliminary Engineering

During the Preliminary Engineering phase of project development, local project sponsors refine the design of the LPA to the extent necessary to complete the NEPA process, taking into consideration all reasonable design options. Preliminary Engineering results in estimates of project costs, benefits, and impacts for which there is a much higher degree of confidence. The proposed project's New Starts criteria are similarly refined in the Preliminary Engineering phase of project development. In addition, project management plans should be finalized, products of the PE effort that demonstrate the technical capability of the project sponsor to advance further in development should be substantially completed, and commitments of local funding sources should be firmed up (if not previously committed).

Preliminary Engineering for a major capital investment project is considered complete when the FTA declares in the environmental Record of Decision (ROD) or Finding of No Significant Impact (FONSI) that the NEPA process has been completed; when the project scope, capital costs estimates, and financial plan are finalized; and when the project sponsor has adequately demonstrated to FTA its technical capability to advance the project into final design and construction. Proposed New Starts and Small Starts projects are evaluated and rated according to criteria set forth in the law. The statutory project justification criteria include mobility improvements, economic development effects, environmental benefits, congestion relief, land use, and cost-effectiveness. The statute also requires the FTA to examine the following when evaluating and rating local financial commitment: availability of reasonable contingency amounts; availability of stable and dependable capital and operating funding sources; and availability of local resources to recapitalize, maintain, and operate the overall existing and proposed public transportation system without requiring a reduction in existing services.

MAP-21 has changed the technical approach for transit-corridor planning in America. The elimination of AA has streamlined the project development

process. Transit corridor planning is more adaptive or flexible, but it also must be constrained by project justification criteria for New Starts and Small Starts by FTA.

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See Also: Busways and Reversible Bus Lanes; Commuter Rail; Federal Transportation Policy; Light Rail Transit; Monorails; Moving Ahead for Progress in the 21st Century Act; Streetcars/Trolleys; Transit Planning, International.

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Transit Cost Allocation Models

Transit cost allocation is part of the larger process of cost analysis for a transit system. The first step in cost analysis is cost determination, the process of gathering information about the total cost of operating a transit system and of any individual service

components that will be analyzed separately. The cost allocation process follows cost determination and involves distributing or allocating costs to specific service components, such as the total operating costs for a group of vehicles that may need to be apportioned to individual vehicles.

Cost allocation models are often used to calculate the expected costs or savings from changes in service provision, or to compare different ways of providing a service. However, not all transit cost allocation models are the same, with one important difference being the type of costs included in different models. For this reason, it is vital to understand the details of the particular model used in an analysis, particularly if the purpose of the analysis is to compare costs between, for instance, public or private provision of services. Cost allocation models are also used to determine how much of the costs of a shared transit system should be paid by the different entities involved.

The Three-Variable Unit Cost Model

Three kinds of costs are considered in transit cost allocation models:

1. Variable costs are those directly linked with providing vehicle transportation, such as fuel, vehicle maintenance, and driver salaries; if transit services are increased or decreased, there would be a change in variable costs, as well.
2. Semi-fixed costs are costs influenced by the services provided, but with a less direct link to changes in those services, such as the cost of rolling stock.
3. Fixed costs are long-term costs that are not affected by marginal changes in transit service levels, such as administrative costs and building maintenance.

Most transit cost allocation analyses use the three-variable-unit cost model, with the three variables in this model being vehicle hours (VH), vehicle miles (VM), and vehicles (V). This model assumes that the total cost of operation is directly related to the number of vehicles in the system, the number of miles that they travel, and the hours of service provided, so that the total expenses of the system can be apportioned to these three variables. This model can also be used to calculate the cost of providing a

particular route or service, as well as the total costs of the transit system, and can be used to calculate either annual costs or costs for a shorter period.

Although the cost of operating any transit system includes fixed, semi-fixed, and variable costs, not all cost allocation models include all three variables, or the full range of costs within each variable.

In a fully allocated model, variable, semi-fixed, and at least some fixed costs are included, although capital costs are usually excluded. In a partially allocated model, variable costs and at least some semi-fixed costs are included. Fully allocated models are often used to compare different transit systems or different modes of transit, while partially allocated models are often used to forecast the changes in costs associated with proposed marginal changes to services.

The choice of which model to use and which costs to include in each category influences the results of the analysis, so it is vital to know in detail which model was used and how it was applied when interpreting any analysis.

Sometimes the inclusion or exclusion of expenses is based on practical factors, such as funding sources. For example, capital costs for a city transit system may come from state and federal funds, and thus not be included in the cost allocation model, which is concerned primarily with the funds acquired from local subsidies and fare collection. Particularly when estimating the influence of proposed service changes, the true quality of a model can only be evaluated after the fact—a good model accurately predicts changes in costs, while a poor model does not.

Alternative Approaches and Models

Researchers have described cost allocation models as one of four approaches to cost modeling. The other three are (1) causal-factor models compute total costs as the sum of the resources used (driver's time, fuel, parts, etc.) multiplied by the unit cost of each resource; (2) regression models use a sample of data to estimate coefficients for variables that influence costs, such as distance traveled, number of vehicles, fleet age, and drivers' salaries, and use the resulting equation to calculate expected total costs with different levels of the variables; and (3) temporal variation models account for the variable costs of providing services at different times of the day, in particular, at peak versus nonpeak travel periods.

Several different cost allocation models can be used. The simplest is the average cost allocation

model; it allocates all the costs of a system to a single output, such as the total distance traveled by transit vehicles, the number of vehicles in operation, or the total hours during which services was provided.

The three-variable unit cost model discussed above represents a step-up in sophistication, because it is one of the models that allocates costs to several operating outputs (for example, vehicle miles, vehicle hours, and total vehicles). This type of model can be described as a fully cost allocated model, without making the partially/fully allocated distinction that is observed in the previous discussion. The most complex models are differentiative fully cost allocated models in which distinctions are made among costs on the basis of temporal variation, activities, or inputs.

Allocation of Operating Costs

Cost allocation is used in another sense with regard to public transit: it refers to the ways the costs of a transit system are allocated among different geographically or politically defined areas. For instance, a bus system might serve both a city and parts of the surrounding county; because the city and county have separate budgets, both need to pay for part of the system's expenses, and cost allocation is used to decide how much of the transit system's budget will be provided by the city and how much by the county. The most common cost allocation methods in this context are to assign costs by route, or according to population, passengers, services hours, or service miles. A combination of these systems may also be used, making the allocation potentially more accurate but also less transparent.

In the route assignment system, the entities involved come to an agreement about which one benefits most by a particular route, and that entity provides funding for the route. In the city-county example, some routes entirely within the city might be seen as providing most benefits to residents of the city and would be paid for by city government, while routes linking the county to the city might be seen as providing most benefits to county residents and thus be paid for by the county government.

A population-based system is based on the number of people served by the system and/or the density of population in the area served. A passenger-based system allocates costs based on the number of riders from the different areas. Service-hour and

service-mile systems allocate costs based on the hours of service or miles of service the transit system provides to each entity.

Criticisms

Some critics charge that the cost allocation models used to answer questions about the cost of a transit trip or the variation in subsidy on different routes or among different classes of passengers mistakenly treat the costs of transit service as uniform, when in fact costs vary widely according to factors such as trip length, time of day, and type of service. They contrast the sophistication of cost models used by airlines and shipping companies with those used in many public transit systems, and charge that the lack of detailed information about the costs of providing different services makes it difficult to set effective policies or manage the transit budget wisely.

Brian Taylor and his colleagues have created a model using data from the Los Angeles Metropolitan Transit Authority, incorporating marginal variations in capital costs, vehicle capacity, and time of day, and found significant cost variation by mode—lower costs for incremental service increases, and higher costs for both peak and off-peak service.

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See Also: Benefit–Cost Analysis of Transportation; Transit Industry, Economics of; Travel Pricing.

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Transit Demographics

Public transportation services are provided in every state in the United States in some form or fashion. Most urbanized areas operate fixed-route public transit services and many rural areas have fixed or demand-response transit services. In addition, many public transportation services are provided for the transportation of the elderly and people with disabilities.

The demographic characteristics of transit riders thus reflect the demographic characteristics of the population of the geographic area served by the provider. Public transit providers use publicly available data to understand the characteristics of the population in their service areas and may periodically survey their passengers to understand the demographics of transit riders in order to enhance or adjust existing services to meet their customers' needs. Publicly available data on demographic characteristics of transit users include the U.S. Census Bureau's American Community Survey (ACS), the Federal Highway Administration's National Household Travel Survey (NHTS), and the American Public Transportation Association's (APTA) onboard surveys.

The characteristics of transit riders vary depending on the form of transit (for example, bus, subway, or train), the trip purposes (for example, work, leisure, or school), and trip frequency. In order to understand transit demographics, one must first define what universe will be measured. Nationally, according to onboard surveys conducted by the APTA, the majority of riders on public transit (59 percent) rode

transit to get to and from work in 2007. Another 11 percent rode public transit in order to get to and from school, 9 percent of riders used public transit to get to dining or shopping, 7 percent for recreational/social reasons, 3 percent to reach medical services, and 12 percent for other reasons.

Because the majority of public transit users ride transit to get to and from work, and because census data is used to help plan for transit services and allocate resources, the ACS reports the modes of transportation used by workers on the journey-to-work (or work commute). The NHTS provides statistics on people in households who used public transportation during a specified travel day and the data can be sorted by trip purpose, including the work commute.

Both the ACS and the NHTS are surveys of a randomly selected sample of the population in households. In contrast, the APTA survey collected demographic information of riders who were riding on public transit vehicles throughout the country.

Characteristics of Public Transit Riders

Nationally, the population using public transportation is racially and ethnically diverse, but over-represented by racial and ethnic minorities, primarily because of differences in socioeconomic resources.

Although the majority of the U.S. population in the early 21st century is non-Hispanic white, representing 68.1 percent of the civilian workforce, only 39.9 percent of workers commuting to work between 2006 and 2010 were non-Hispanic white, according to the ACS. Non-Hispanic blacks were more likely than any other group to ride public transportation and accounted for 23.9 percent of work commuters using public transportation.

Two of the fastest-growing groups in the United States, Hispanics and Asian and Pacific Islanders accounted for 24.1 percent and 5.6 percent, respectively, of public transit riders on the journey to work. The APTA survey of riders found similar statistics when surveying passengers riding on public transit systems in 2007. Continued growth in the minority population, and in particular in the Hispanic and Asian and Pacific Islander population, will mean that public transit riders will become increasingly Hispanic and Asian and less non-Hispanic white.

Public transportation plays an important role in providing transportation for those who do not have access to a personal automobile or other forms of

transportation, and, as a result, it is often associated with people who have lower incomes. However, public transportation can also provide transportation to those who have access to vehicles but wish to avoid road congestion; reduce transportation expenditures for gas, maintenance, and parking; or choose to ride transit for environmental and other reasons.

As more people locate to and live in major urban areas, where public transportation is widely available, more people will ride public transportation. In fact, according to the NHTS, 52.7 percent of commuters using public transportation of some form in 2009 had incomes of \$50,000 or more.

The work commute remains the single most cited purpose for taking public transit. Thus, it is not surprising that most transit users are in the primary working ages of 16 to 64. In fact, the majority of transit riders on the work commute (57.4 percent) were between the ages of 30 and 64 in 2009, according to NHTS, while only 8.4 percent were 65 years or older and 34.2 percent were younger than age 30.

In the early part of the 21st century, the majority of riders on public transportation were women, accounting for 52 percent of all public transportation riders, according to APTA onboard surveys, and 50.8 percent of riders on the work commute, according to the NHTS.

Characteristics by Mode Type

The demographic characteristics of riders vary by the type of transit system used. According to the NHTS, 36.3 percent of bus riders on the work commute were non-Hispanic white in 2009, compared to 48.8 percent of riders on rails. African Americans accounted for 27.6 percent of bus riders and 20.6 percent of rail riders. Hispanics accounted for 26.8 percent of bus riders, but only 14.5 percent of rail riders, likely a result of the geographical distribution of rail systems relative to concentrations of Hispanic people. Asians and Pacific Islanders accounted for 6 percent of bus and 10.5 percent of rail riders, respectively.

The majority of bus riders on the work trip are women (55.4 percent), although they are the minority, at only 44.3 percent, of riders on subways and commuter rail. Riders on rail are older, on average, than those riding public buses. Only 18 percent of commuters riding some form of rail (subway, commuter rail, trolley, etc.) were under the age of 30, compared to 29.9 percent of public bus riders.



Commuters on a subway platform in Toronto, Canada, in 2011. The demographic characteristics of transit riders in the United States have been found to vary by the type of transit system used. For example, the majority of bus riders on the work trip are women (55.4 percent), although they are the minority, at only 44.3 percent, of riders on subways and commuter rail.

Those riding public subways and trains are more likely to be riding public transit system as a matter of choice than those riding public buses, who tend to ride buses because they do not have access to a personal vehicle or other forms of transportation. Public rail riders are more likely to be in the prime earning ages, and the income distribution of public transit riders on rail transit are skewed toward higher income ranges. Whereas 61.7 percent of bus commuters had incomes of less than \$50,000 in 2009 and 20.8 percent had incomes less than \$15,000, only 29.1 percent of commuters riding commuter rail, subways, and other rail systems had incomes of \$50,000 or less.

Immigrants

Immigration has been an important component in the growth of the United States throughout its history. Many larger urban areas serve as gateway cities: places where new immigrants arrive and live

with or around other immigrants who can assist the new immigrant in navigating their way through a new culture. Public transportation can play an important role in helping immigrants who may have no other means of transportation to travel to work, school, and other activities. However, language barriers and unfamiliar ways of navigating public transit systems may hinder immigrants from using public transit systems.

To remedy these issues for immigrant people, public transportation agencies must understand the different immigrant populations present in their service areas and develop strategies to eliminate language and other cultural barriers. In time, immigrants assimilate into the culture and adopt the transportation use patterns of nonimmigrants. Transit agencies, therefore, need to not only find ways to eliminate barriers to ridership among new immigrants but also find ways to retain immigrants as riders of public transit.

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See Also: Commuting; Transit Ridership; Transportation Statistics and Databases; Travel Patterns by Income; Travel Patterns by Race/Ethnicity; Travel Patterns of the Elderly; Travel Patterns of Women.

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Transit Dependence

Transit dependence (also known as transit captivity) refers to individuals or markets that rely on transit for most or all of their travel needs. This is usually discussed in contrast to “choice” users who have access to a private vehicle but choose to use transit. An individual is considered transit dependent if he or she has no driver’s license or lives in a household without a private vehicle.

Transit captivity is also discussed at the market or neighborhood level, where demographic factors such as age, disability, or low income are identified as indicators for transit dependence. In the United States, about 30 percent of the population 5 years of age and older is considered transit dependent.

Transit captivity is an important concept in transit planning and modeling, because captive markets account for around 70 percent of transit trips in the United States. They are seen by transit agencies as a secure market because it is assumed that captive users who have no other transportation options will always use transit. Although this may be the case in the short term, if the captive market is neglected, the long-term effect could be users changing their behavior, such as by purchasing an automobile, changing home location, or forgoing trips.

Transit agencies tend to focus on attracting “choice,” or discretionary, riders, because it is assumed that those users will only select transit if it is superior to the car in regard to cost, time, and/or convenience. Discretionary users are more likely to change their transit use in response to changes in fare, travel time, and reliability than captive users.

The proportion of transit-dependent travelers using a system depends on the transit mode and network coverage. Captive riders tend to dominate in low-quality, infrequent, and dispersed networks typified by local bus systems. In contrast, high-frequency, radial commuter-oriented networks, typified by light and heavy rail, tend to attract a larger proportion of choice riders. This is because

efficient, radial rail networks are more likely to be a competitive alternative to private motor vehicle travel and therefore attract choice riders. In contrast, local bus systems are usually uncompetitive compared to private cars and are more likely to be used by transit-dependent populations that have few travel options.

In much of the United States, transit-dependent households face a transportation environment particularly unsuited to their situation. Rapid decentralization of housing and jobs has dispersed travel destinations in a way that puts many locations out of reach of public transportation. Transit-dependent households generally have poorer access to jobs, education, and other important destinations than households with access to a car.

In American cities, transit-dependent households can access only 40 percent of metropolitan jobs within 90 minutes of travel on transit. Low-income job seekers are more likely to find work if they have access to a car than if they are reliant on public transport. Studies in the United Kingdom have found that many job seekers, especially young adults, cite a lack of personal transport as a significant barrier to finding work. People without a car are much more likely to miss medical appointments, have difficulty accessing grocery stores, and may forgo social activities because of their lack of transport options.

Equity and Environmental Justice

Transit dependence often plays an explicit or implicit role in discussions about transit and social equity. This is because transit dependence is closely associated with socioeconomic disadvantage, low income, and social marginalization. Household car ownership is closely tied to household income; some 60 percent of American households in the lowest income category do not have access to a vehicle, as compared to only 8 percent of American households overall. Ethnic minorities are also more likely to live in households without access to a car and are more likely to take public transport to work.

As mentioned above, transit-dependent populations tend to be over-represented in low-quality local bus systems and under-represented in efficient rail networks. This can result in a tension between the two objectives of transit systems, which are to provide an economically efficient system that

reduces road congestion and environmental pollution, and to provide a basic level of access for all persons, especially the transit dependent.

The former objective is best served by commuter-oriented radial transit systems, often at the neglect of dispersed transit-dependent markets with diverse travel needs. The latter objective is served by lower-patronage transit networks with broad geographic coverage and low service frequency. In an attempt to improve the economic efficiency of transit systems, some cities have resorted to paying for improvements to commuter rail systems (which primarily benefit white-collar, middle-income workers) through increasing fares and cutting back local services (which disadvantages low-income, transit-dependent communities).

In the United States (and to a lesser extent the United Kingdom), the social equity implications of these decisions are generally played out under the banner of the environmental justice movement. The origins of the movement date back to the 1960s, stemming from Title VI of the 1964 Civil Rights Act, which states that “no person in the U.S. shall, on the ground of race, color or national origin” be excluded from any federally funded program or activity.

Although originally applied primarily to land use issues, such as zoning and the placement of landfills, more recently the term has been applied to transportation issues and supported by more executive and federal orders through the 1990s. Under legislation, any change to a transport system is meant to consider whether programs will have a disproportionately adverse impact on minority and low-income populations.

For example, if a new light rail system will be funded by increasing bus fares, an environmental justice assessment should be undertaken. If it is found that high-income workers will primarily benefit from the light rail system, whereas low-income (transit-dependent) workers will be disadvantaged by the increased bus fares, then mitigation strategies must be put in place to reduce the imbalance (for example, by increasing bus levels). Environmental justice issues have resulted in at least one successful class action against a transit operator.

Choosing Transit Dependence?

Much of the discussion of transit dependence presumes people are forced into dependence as a

result of circumstances beyond their control. This is especially true in the United States, where most cities and rural areas are highly automobile-oriented and transit networks are sparse.

However, it is worth noting that some people choose to be dependent on transit, that is, they are able to purchase and drive a private vehicle but choose not to. These individuals tend to live in cities with dense transit networks and restrictions on private vehicle use, such as high parking charges or congestion pricing. There is increasing evidence that people of Generation Y (or millennials) are more likely to live in accessible urban areas, are driving less than previous generations, and are more likely to delay or forgo acquiring a driver's license.

Furthermore, there is some evidence that the most common measure of transit dependence—no household vehicles—is becoming less valid with the rise of car-sharing companies (called car clubs in the UK). In many cities, households that may have traditionally been locked into transit dependence because of the expense of owning and running a car can now use a car sharing service for some trips at relatively low cost.

It is unlikely that transit dependence will ever be fully divorced from issues of socioeconomic disadvantage. Yet, emerging transportation options raise interesting questions about how transit dependence will be conceptualized and addressed into the future.

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See Also: Accessibility and Mobility; Buses; Jitneys; Paratransit in Developing Countries; Reverse Commuting; Social Equity and Discrimination in Transportation; Spatial Equity Analysis; Transit Demographics; Transit Ridership; Transportation and the Disadvantaged.

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Transit Fares

Transit fares are fees that are charged to passengers for use of a public transportation system. Broadly defined, public transportation systems include any passenger service that is available to the general public. The discussion presented here focuses on transit fares in the context of urban mass transit and commuter rail systems. In this discussion, the terms *boarding* and *unlinked trip* refer to the same thing: a ride that is taken on a single transit vehicle.

In contrast, a linked trip covers the entire journey between the traveler's origin and destination, whether the journey involves a single boarding or multiple boardings. In a linked trip with multiple boardings, the first boarding is often called the initial boarding and each subsequent boarding is called a transfer. Most transit operators offer a heavily discounted rate or no charge for transfers. The term *fare system*, which is commonly used but somewhat vague, refers to all components of fare collection, including the creation of a fare structure or the determination of fare prices and policies, the types of fare products or media that are offered, and the collection of fares.

Fare System Objectives

The primary objective of most fare systems is to generate revenue that helps cover operator costs. The concurrent maximization of ridership is also desirable for many reasons. First, higher ridership suggests that a large number of individuals find the transit service to be a beneficial transportation option, an important achievement because the purpose of public transit is to provide mobility to the population. Second, high ridership facilitates progress toward other social goals, such as improving air quality, reducing road congestion, reducing parking facility needs, and improving accessibility.

Transit operators usually seek to balance revenue needs with ridership maximization, but fare systems typically do not generate enough revenue to cover all costs that are borne by the transit agency. The balance of costs is made up in part by subsidies.

When designing their fare systems, operators frequently target additional objectives. Transit agencies often offer an array of fare products to better meet the needs and preferences of their customers. Various fare collection technologies, such as stored value (magnetic stripe) cards, can make fare collection faster, less costly, and more reliable. Furthermore, agencies can construct policies that allow customers to transfer inexpensively, helping keep service affordable to customers when direct service between the origin and destination is not provided or is not preferred.

Fare Structures and Key Elements

To help achieve these objectives, each public transit agency establishes a system of fare pricing and related policies—called the fare structure—to which its riders must adhere. Fare structures can include a variety of schemes to determine how much fare to collect from each passenger. Flat fares are prices that do not vary by distance, time of day, or other dimensions. Variable or graduated fares, unlike flat fares, vary. Examples include the following:

- Distance-based fares vary depending on the length of the trip
- Zone-based fares are similar to distance-based fares, but use a simplified system in which nearby stations are typically grouped together (into a single zone)
- Peak/off-peak fares vary by the time of day or the day of the week
- Transfer policy determines the price of boarding additional vehicles (after the first boarding), and can include stipulations on when or where transfer rates may apply
- Discounted fares allow some categories of riders to ride for a reduced price (or for free)

While these elements are commonly observed across public transportation fare systems, an individual system usually uses only two or three of these elements.

Transit agencies typically use either flat fares or variable fares, although there are some examples (discussed later) of fare systems with elements of both. Transfer fares are relevant for systems with a flat-fare structure and in systems where fares vary by time of day or day of week. Transfer fares are not

used in systems that are entirely distance- or zone-based because the fare price in such systems depends on the length of the trip rather than the number of vehicles boarded. Practically all transit agencies offer discounted fares for some passengers, including seniors, riders with mobility impairments, or students. This is true regardless whether the overarching fare scheme is flat or variable. Agencies also typically offer multiple ways to pay for fares, such as a flat rate or an unlimited pass. Similarly, most agencies allow customers to pay with a variety of media, such as cash, stored-value cards, and smartcards.

Flat Fares

A flat fare is a fixed price that is charged to passengers each time they enter the system. The price may differ for population subgroups, but the basic mechanism is the same.

A key benefit of flat fares is that they are simple for riders to understand and remember. From the operator perspective, collection of flat fares is straightforward but generally requires more handling than passes. Flat fares and unlimited passes can be more simplistic than variable fares for operators to administer, although these differences are being reduced with advancements in smartcard technology.

Agencies generally offer several ways for customers to pay flat fares. The most basic method is cash. Tokens (coin-like slugs) were once popular, but their usage decreased when stored-value cards became common. The value that is held in stored-value cards can usually be replenished through ticket-vending machines at transit or retail locations. More advanced technologies, such as smartcards and contactless credit cards, are a variation that allows replenishment using an Internet-based account.

Transfer Fares

Transfer fares apply to the second or third (or subsequent) boarding of linked trips that involve multiple boardings. Transfer fares are usually much lower than the initial boarding rate; sometimes they are free. Until recently, operators typically provided a paper ticket to the passenger upon the first boarding to use for boarding subsequent vehicles. As the usage of cash and tokens declines, most transit systems now use magnetic-stripe (that is, stored-value) cards or other media to provide transfers.

Transfer policy historically has focused on facilitating travel between origins and destinations that

are not directly served by a single transit vehicle. Using this policy, operators can effectively price a trip requiring two or more boardings at a level that is the same or slightly higher than a one-vehicle ride. Therefore, while the burden of transferring from one vehicle to another may still discourage some customers from using transit, operators attempt to keep the total fare of such trips in line with one-seat fares so that fare prices do not create another impediment.

There are two transfer policies in common use today. One policy allows the riders to use the transfer fare to make transfers (usually up to two) en route to their destinations. In general, the transfer must be used within a specified time window. This policy prohibits or discourages riders from using the transfer rate for the return trip.

The other commonly used policy is similar, but riders are permitted to use the transfer rate for the return direction. The latter policy creates a flexible fare mechanism that can effectively be used by passengers as either a flat fare or something akin to a very-short-term unlimited pass.

Discounted Fares

Fare price discounts, where riders pay less than the full posted fare, are offered to riders who meet certain conditions. If the fare structure includes a flat fare, then the flat fare usually is the basis of comparison when evaluating the discount. Discounted fares are offered in most transit systems worldwide and can be classified based on the following:

- The fare instrument that is used and/or the amount of trip-making for which it is utilized
- Passenger characteristics
- The origin and/or destination of the trip
- The time of the day or day of the week (time-of-day discounts are discussed under variable pricing)
- Discounts based on fare instrument or frequency of use

Transit agencies frequently set different prices for fares paid in cash and fares paid using other media. Because of the high costs of dealing with cash, agencies may penalize the use of cash fares in comparison to other fare media, such as fare cards and transit passes. Regardless whether the cash

fare or the card fare is considered the “true” base fare, cash-paying riders often pay more than other passengers for each trip. Unlimited-ride passes allow riders to take as many rides as they want within a specified time frame. For example, a one-day pass permits the rider an unlimited number of rides in a single day. Pass prices usually provide a discount for frequent usage. As such, regular riders may essentially receive a small discount per trip compared to passengers paying a single-ride fare, and heavy users end up receiving more significant discounts. At the same time, pass holders who end up not using the transit system as much as they anticipated may overpay for those transit trips they do make.

Similarly, some agencies offer discounts to riders who purchase a set amount of rides or stored-fare value at one time. For example, a 20 percent discount may be provided when a 10-ride ticket is purchased. Alternatively, a discount may be offered when a minimum value threshold is met or exceeded; for example, a 10 percent discount may be offered when a stored-value card is replenished with at least \$20.

A number of transit agencies offer a special pass to university students (sometimes called a U-Pass), which is priced at a very low rate and covers a semester, quarter, or other term. In many but not all regions, the low cost of the pass is somewhat offset by the fact that all active students pay for the pass (often as part of their general student fees for each semester), regardless how much they use the transit system. This particular type of discount is partially related to the fare media, but is primarily related to passenger characteristics, since the pass is restricted to actively enrolled university or college students.

Discounts: Passenger Characteristics

In addition to providing fare discounts to university students, transit systems commonly offer reduced fares to children. In large urban areas, public transit serves as a substitute for school bus service and discounted fares are justified on that basis. High school and sometimes middle school students may have passes provided by the school district that further reduce the cost to the student.

Despite this policy background, school district revenues do not necessarily go to transit agencies to make up the difference in fares. Instead, state

legislatures historically have provided some general revenue for the purpose of making “whole” the transit agency, although this can be cut back during budget crises.

Charging lower fares for children making non-school trips is typically justified on social welfare grounds, that is, that public transit would be unaffordable for families with several children. Very young children typically ride for free.

In the United States, federal law requires agencies to charge seniors at least 50 percent less than the regular adult off-peak cash fare. Some agencies allow seniors, or some categories of seniors (for example, low-income seniors), to ride for free. One drawback of fare structures that delineate among multiple classes of passengers is that different fare media often are needed to account for their rides. This complicates the management and maintenance of the fare system. While low-income riders occasionally receive discounts from the transit agency directly, it is more common for outside social agencies to provide passes to their clients and not directly involve the transit agency.

Discounts: Origin and Destination of Travel

Discounts (or penalties) that are applied to specific origin and destination pairs of transit trips are conceptually similar to zone-based fares. Some typical examples of this fare policy are surcharges for trips going to or from a regional airport and free fares for trips made within downtown areas.

Airport surcharges are often justified on the grounds that the cost of the airport extension has to be paid for separately from the rest of the transit system. Surcharges can also help cover other airport transportation costs, including traffic handling and traveler information costs.

Free downtown fares, in contrast, are viewed as a way of promoting transit generally and specifically encouraging people to use transit for shopping and other business in the downtown core. They do not typically have a dramatic fiscal impact on the transit agency because few people would pay full fare for such short trips. Further, the fact that the free downtown service is available during the day may induce some people to take transit to work rather than driving (where the car might otherwise be needed for in-city trips). These free trips may be restricted to off-peak hours to reduce interference with commuter travel.

Variable Pricing

Variable fares generally are defined as fares that vary based on trip characteristics or service types. Variable pricing means that the cost of a transit trip depends on its characteristics. Fares may vary based on trip distance, the “zones” the passenger travels through, time period, travel time, or type of service. In the most complicated fare systems, a combination of characteristics (such as distance-based fares that vary by time of day) may be utilized.

Variable fares can benefit the transit system operation in several ways. For example, peak fares can shift travel to the off-peak or the peak-period shoulders, relieving crowding and improving travel-time reliability during the busiest transit hours and making more efficient use of off-peak service. Distance-based fares may help operators recoup costs more efficiently (and possibly more equitably) than flat fares. Higher prices for faster or higher-quality service can increase revenues using a market-based approach that is acceptable to the ridership population.

In comparison to flat fares, however, variable fares are relatively complex for passengers to navigate and for operators to administer. For example, if fares vary for peak and off-peak, then the number of flat fares can effectively double. When applied to unlimited pass products, the concept of fare variability becomes more complicated because it adds a restriction to a fare product that otherwise permits unlimited travel. Fare collection technology must be sophisticated enough to determine the correct fare and to do so reliably. Distance-based or zone-based fare collection can be expensive to integrate because of special capital requirements, such as installing exit barriers.

Service Quality

Differential pricing for various levels of speed and type of service are often used. For example, many systems charge a premium for rapid bus because it offers faster service than a local bus. Similarly, some systems charge different rates for rail and bus to account for their perceived differences in quality of service.

Fares Based on Distance or Travel Zones

In distance-based pricing systems, the amount of fare to be paid increases with the length of the trip. Depending on the operator, trip length is measured using track miles or Cartesian distance.

Infrastructure requirements typically include entrance and exit barriers or another form of operator monitoring to assess the distance traveled. Zone-based pricing is a simplified form of distance-based pricing where groups of stations are treated as a single unit (or zone) for purposes of fare pricing. Regions often use a small number of zones to maintain simplicity.

Distance-based or zone-based pricing is commonly used by commuter rail systems, where collecting these types of fares is relatively simple. The main reason for this is that because most commuter rail passengers are traveling between their homes and a downtown area, operators have enough time to collect fares and to determine the proper fare to charge the occasional passenger traveling to a destination other than downtown.

In contrast, distance-based or zone-based pricing is more difficult to design and administer—and, therefore, relatively uncommon—in urban mass transit systems, where travel patterns are more geographically dispersed and bus-to-rail transfers are common.

Fares Based on Time of Day of Travel

Many transit agencies charge different prices for peak and off-peak service. Common forms of time-of-day pricing include lower fares in the off-peak period and/or on the weekend (or a single weekend day). Peak periods tend to be defined as approximately 6 A.M. to 9 A.M. and 3 P.M. to 6 P.M., although this definition varies by agency. Lowering fare prices in the off-peak is justified by the fact that fare elasticity is higher in off-peak periods, meaning that a discount during these times will generate a larger percentage of new riders than during the peak periods.

Furthermore, transit vehicle utilization rates tend to be relatively low during the off-peak periods. From a policy perspective, this strategy helps attract riders to ride more during these underutilized periods. Depending on how the peak periods are defined, it might be possible to shift some transit riders away from the peak usage period to the off-peak, which also alleviates the need to purchase additional transit vehicles to be used only for peak demand.

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See Also: Bus Rapid Transit; Commuter Buses; Commuter Rail; Subway Systems; Transit Fares, Elasticity of Demand of; Transit Fares, Media and Collection Systems and; Transit Ridership.

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Transit Fares, Elasticity of Demand of

Transit fares are a component of system management that can be adapted and tested at different levels, thus yielding an elasticity of demand experienced largely as changes in ridership levels. Demand can be measured in the number passenger boardings; total passenger miles provided; or, on a somewhat more sophisticated plane, mean revenue miles. Some studies have indicated that the regular passengers of a given transit service tend to be more sensitive to changes in fare price and in other variables of that service. In a sense, they become better informed over time.

They also build up a set of expectations beyond fare price; these involve factors such as trip time, seat availability, comfort level, effects of weather conditions, and experiences at different times of the day. Two non-fare factors that seem particularly potent are anything that has the effect of delivering reduced waiting time, and the availability of express services.

Extensive surveys of urban transit systems have attempted to determine the extent of these and other causal factors of fare elasticity. Generally, these surveys are weighted to de-emphasize

extraordinary ridership increases, such as those generated by special deep discount appeals to strictly defined demographic subsets (for example, university students).

It has been discovered in the aggregate that regular transit riders are indeed sensitive to fares. They tend to reward stable or declining fare levels with increased ridership—as much as 5 percent annually, or even more in some studies. Still, in practice, the effect of fares seems universally to place second to the effect of service expansion or contraction.

Among tertiary factors, it has also been noted that there are at least three fairly potent demand determinants that are out of the control of administrators to increase or decrease—but that seem to have considerable staying power. The three quite often cited are the income level of riders and potential riders, the cultural tastes and preferences of such riders, and the prices these riders pay locally for related goods or services.

Case studies conducted in transit markets as diverse as Victoria, British Columbia, in Canada; Santiago, Chile; London, England; the West Bank of Palestine; and in the United States, Houston, Texas; Los Angeles and San Diego, California; Portland, Oregon; and Seattle, Washington, seem to verify rather consistently most of these findings and observations.

However, there is also considerable debate over the ability of various transit administrations to gauge realizable fare elasticity due to the fact that transit mode fare changes often occur across several modes simultaneously, and the elasticity effect on individual modes is clouded by this problem.

Evolution of Models

Originally, transit demand and traffic flows were analyzed with tools that, at their core, used the gravity model, a concept formalized in the 1950s by researcher Alan Voorhees. This stated that increasing distance between two transportation points yielded decreasing likelihood of passengers traveling between those two points. In the model, the concept of “distance” could also be interpreted as time, or alternately as cost. Judged from the point of view of fare elasticity, where fare is increased, ridership is most likely to decrease in proportion.

This theory has held up well in general and has supported many large and small decisions in transportation planning and the administration of fare

levels, service extensions, and related factors. Its utility has flagged somewhat, however, in analyzing systems with a multiplicity of external and internal factors, such as complex demographic makeup in a market, intermodal inputs and influences, ecological and environmental concerns, and the like.

In his 2013 scholarly review and synthesis *Understanding Transport Demands and Elasticities*, researcher Todd Alexander Litman, with a focus on serving the transit authorities of Victoria, British Columbia, began by establishing a broad set of transport demand-affecting factors derived from six general categories of market and social context. Within each of these six categories, Litman identified the following range of factors:

1. Demographics, including the number of people (residents, employees, and visitors), employment rate, wealth/incomes, age/life cycle, lifestyles, and preferences
2. Commercial activity, including number of jobs, business activity, freight transport, and tourist activity
3. Transport options, including walking, cycling, public transit, ridesharing, automobile use, taxi services, telework, and delivery services
4. Land use, including density, mix, and walkability.
5. Connectivity, transit service proximity, and roadway design
6. Demand management, including road use prioritization, pricing reforms, parking management, user information, and promotion campaigns
7. Prices, including fuel prices and taxes, vehicle taxes and fees, road tolls, parking fees, vehicle insurance, and transit fares

Of the above factors and categories, it can be said that most are transferable from one market to another, so long as the administrators of the analysis feel confident that each of their local conditions match the definitions.

Some jurisdictions will, of course, be less interested in many of the factors listed here; they can simplify and substitute like for like in order to produce a modeling system that most accurately reflects the challenges and backdrop of their actual marketplaces. Thus, the data inputs for such a

model can be tweaked to account for unusual (from a regional sense) levels of automobile ownership, for areas of extreme traffic congestion, or to test trip time indices, parking availability, and prices in areas along the transit routes being studied, and many other variables. This type of framework can reliably be mixed and matched to emphasize and de-emphasize certain influences. Investigators have a free hand to change the weighting of factors so that data input for a given study results in outputs that yield realistic answers to the questions that the local transit officials are mandated to explore or are most interested in answering.

It may be that in one region, transit customers are faced with few alternatives; their apparent tolerance for higher transit rates could be masking their just-below-the-surface dissatisfaction with the transit equation they feel they must put up with. This can engender a risky sense of false confidence on the part of transportation authorities in that region, and the introduction of a competitive service with low cost of entry—for instance, an express bus operator with its markedly scant infrastructure needs—could suddenly reveal how loyalty to and satisfaction with the main transit system had been undermined.

In a similar manner, a string of severe weather events could cause repeated intense disruption of a long-standing transit system, compelling riders to seek alternatives. Once the dislocation has passed and the transit system has been fully restored, however, the transit authorities may find that a gap has opened in anticipated ridership levels. It may be that some part of this gap represents riders who have developed a satisfactory alternative that they elect to stay with, even in the face of fresh rounds of fare-cutting by the transit authority.

In such a case, the inputs of income level, transportation infrastructure, and other factors will seem to be identical to the status of the market prior to the series of storms—but the weighting of these factors will have to be entirely reconsidered, at least as they apply to that segment of the former ridership that has “flown the coop.”

Service increases and fare reductions appear to be the two most powerful ways to increase ridership of public transit systems. The effect has, in a number of cases, been shown to be especially pronounced when the metropolitan area under study happens to be experiencing overall economic and job growth.

Many studies in various markets and diverse contexts and environments seem to have validated these commonsense findings.

However, the question remains over how to balance transit system fiscal soundness and how to measure the optimal fare-price level a system can achieve while still retaining a critical bulk, if not most of, its extant ridership. The concomitant question is how thorough and of how high a quality must service levels be maintained in order to support this optimal balance.

Angles of Approach

In addition to the various types of demand-affecting factors, there are other ways to approach the data available in a transit market. For example, some types of trips are valued higher or lower than other types. An emergency trip would be ranked as the highest-value trip and thus be the most resistant to fare increase. Commuting to work is generally the highest value after emergency travel.

In a 1980 to 1981 study within the Southern California Rapid Transit District (SCRTD) in and around Los Angeles, the relative fare elasticity distinction of these value types was starkly revealed as the result of a fare increase regime. All aspects of the fare structure were altered at once, including cash fares, transfers, monthly passes, and special user discounts. The average fare increase amounted to 27.3 percent; the overall ridership across SCRTD immediately declined by 1.9 percent. Revenues, however, rose by 24.5 percent and stabilized.

Among the clearest results was that riders making work trips exhibited no fare sensitivity—in fact, their frequency of ridership increased during the period of the study. Those riders making non-work-related trips decreased their frequency of use. Demographically, those transit riders with low incomes, those with no available cars, and the elderly were less likely to decrease or discontinue their SCRTD use; in essence, these riders assigned a higher value rank to non-work trips than other groups did.

Value rankings such as these can be plotted visually. Further along the descending value curve from emergency and work trips would come commuting to school, major shopping needs trips, travel to special events and socializing trips, and, finally, spontaneous entertainment or shopping trips.

By assigning a given value to each type of trip, these value points can be plotted against fare prices.

The result will be a demand curve, showing how many or how frequently a trip type will be taken. This demand curve reveals price sensitivity; it can be plotted using real inputs in a test of different fare prices and by counting the number of trips that result. In a London Transport ridership analysis that covered two decades of activity (1970s and 1980s) on both the Underground and surface bus systems, demand curves were developed to account for such value-oriented system and context factors as run-miles for each mode, employment, retail sales, tourism, auto ownership, and key one-time events.

In such a study with its value-focused bias, fare price, can be plotted against number of trips, or consumption, with a steeper downward curve revealing lower demand elasticity. That is, the drop-off in consumption is greater in reaction to higher fares. When the curve is more gradual, the drop-off in consumption is more elastic; the riders are not cutting trips as quickly in reaction to the higher fares. The curves can also be plotted against time, which can reveal the persistence or dwindling of demand-elasticity impact as a result of fare increase.

In the London Transport case, for instance, it was demonstrated that two-thirds of the change in demand occurred immediately in the case of the bus mode, with the remaining change taking shape over the course of one year or somewhat longer. However, virtually all of the change in demand for the Underground mode occurred immediately.

The efficacy of fare changes upon demand levels can also be tested within distinct segments of a transit system. Beginning in the 1970s, for example, transit administrations in Portland, Oregon, and Seattle, Washington, tested the viability of fare-free zones in downtown areas where municipal government and business leaders were interested in building up attendance and transactions among the core retail and cultural attractions. In each case, it was found that both local residents and transient tourists were increasing their use of outlying, fee-based segments of the transit systems due to their interest in the downtown attractions and their desire to access the fare-free segments of the transit systems.

Fare-free ridership in the downtown zone of Seattle reached an estimated 7.6 million annual trips, or 25,000 per weekday. This represented a 200 percent increase and created a demand surge at peak times that was met largely by adding bus service in the core business district. Additionally,

an increase of up to 2,000 daily transit trips were recorded outside the fare-free zone, helping cover the costs of the free service.

In Portland, where the fare-free zone was accompanied by fare changes in other segments of the system, it was found that more than 40 percent of survey respondents had increased their use of the metropolitan transit system. Of these, 35 percent credited a newly introduced monthly discount pass option, 27 percent credited the fare-free zone directly, about one-fifth credited a new flat-fare offer, while another one-fifth credited increased service overall.

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See Also: Automated Road-Pricing and Toll-Collection Systems; Highway/Road Capacity; Telematics; Traffic Forecasts; Transit Fares; Transit Systems, Marketing Research and Public Relations for; Value Pricing.

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Encyclopedia of
TRANSPORTATION

Transit Fares, Media and Collection Systems and

Cash is the simplest way to pay for transit fares, and many bus, subway, and commuter rail systems began operations by accepting only cash; some continue to accept it today. However, cash has several disadvantages, including the risk of theft, delays caused by the time required to make change and confirm that the correct fare was paid, mechanical problems with collecting paper money (especially in the United States, where dollar coins are not in common use), and the time and effort required to regularly collect cash from the fare boxes and count and sort it before depositing it in the bank. Studies have also shown that passengers are more sensitive to increases in fares when they are paying cash than when paying by other means. For these reasons, many transit systems offer alternatives to paying fares in cash, most commonly through tokens, passes, or electronic stored-value cards.

Fare Collection

Fares may be collected before the passenger boards the vehicle, at the time of boarding, after the trip is under way, or when leaving the vehicle. The first method is common in commuter rail and subway systems, as well as in all systems that use unlimited-ride passes (in which case the fare is collected when the pass is purchased).

Subway systems often have a turnstile or gate system that requires paying a fare to access the train platform, or they may use the self-service fare collection (SSFC) method, which is also used by many rail systems. In an SSFC system, there is an open train platform (that is, there are no barriers to prevent anyone from entering it) and passengers purchase tickets in advance. They then cancel them in a machine shortly before boarding.

The canceling process stamps a date and time (and possibly a location) on the ticket, so it cannot be used again, and the honor system—along with the sporadic presence of train inspectors—encourage travelers to abide by the rules and pay their fares. One major advantage to SSFC is that all doors may be used to board the train, reducing delays; another is simpler construction of stations, because turnstiles or fare gates are not required.

Some cities (for example, Curitiba, Brazil) use a bus rapid transit system in which passengers prepay their fares at above-ground stations equipped with turnstiles and a raised waiting area separated from the sidewalk. Because passengers must pay a fare to enter the station, they can go directly onto a bus once they are inside the station.

However, it is more typical for bus systems to use a “pay as you enter” system, in which passengers pay their fare as they board the bus and pass by the driver. They may deposit money into a farebox or swipe a stored-value card through a card reader. Although this system is simple and solves the problem of limiting access to people who have paid a fare, it can cause delays in boarding, as each fare must be collected before the passenger can board.

In some systems (for example, the public bus system in Bangkok, Thailand), the problem of delays is avoided by allowing passengers to board and then having a fare collector get their fares while the bus is traveling; however, this system is labor intensive and thus expensive, particularly in high-wage countries. Collecting the fare as the passenger exits may also help prevent delays and is most practical on routes where many people board at one or a few locations but get off at many different locations, so the fare collection process is more dispersed.

If a route collects passengers from many locations and delivers them to a central location in the morning, with the reverse in the evening, as is typical of many commuter routes, the “pay as you enter” system may be used in the morning and “pay as you exit” in the evening. The “pay as you enter” and “pay as you exit” systems may also be combined on a single trip, if the transit system consists of multiple zones. In this case, passengers pay one fare to board and a second fare if they exit the system after the zone marker.

Subway and Bus Tokens

Many transit systems use tokens, coinlike objects of a distinctive size and weight, which can be collected through turnstiles or fare boxes. Using tokens speeds the fare collection process, avoids the need to make change, and allows the transit system to set fares without regard to the coinage needed to pay them.

For instance, when the New York City subway system introduced the subway token in 1953, the

turnstiles that collected fares had been designed to accept only a single coin. That system had worked when the fare was 5 cents, and later when it was raised to 10 cents, because the turnstiles were set to accept first a nickel, then a dime. However, when the fare was raised to 15 cents in 1953, engineers could not manage a way to alter the turnstiles to accept two different coins for a single fare (a nickel and a dime), and thus the token was invented as a sort of alternative currency that was sold for 15 cents. The city of Baltimore, Maryland, adopted tokens for a similar reason, when the fare was raised from 5 cents to 6 cents in 1919.

New York stopped selling transit tokens on April 12, 2003, and by that point only about 8 percent of rides were paid for by tokens, with most riders using the electronic, stored-value Metrocard, which had been available since 1994. Besides putting an end to a crime called "token sucking" (jamming a turnstile so tokens would not go through, then stealing them by sucking them back up through the slot), ending the use of tokens also eliminated the cost and labor involved in delivering them to token booths, selling them to passengers, and removing them from the turnstiles.

Ending token sales also eliminated the risk of theft during the transportation of tokens, a significant consideration because tokens were valued at \$1.50 each by 2003. Finally, the city had lost considerable revenue over the years resulting from counterfeit tokens, the use of foreign coins, or tokens from other systems that were close enough in size and weight to be substituted for subway tokens.

Announcing a fare increase without changing the token also presented a problem to the transit systems, because riders could easily hoard tokens purchased at the lower price and use them after the price was raised. To attempt to prevent this, officials sometimes announced that the token would be changed at the same time as their fare increase, then apparently reversed this decision at the last minute.

Not counting commemorative tokens, five token designs were used in the New York City system over a 50-year period; the first two were a metal disc with a "Y" cut out (to change the weight of the token so a coin or slug could not be substituted), followed by a solid brass token, then a bimetallic token, and finally a token with a pentagonal cutout. When the transit token was phased out in 2003,

the fare was raised to \$2 (from \$1.50); to prevent hoarding, subway turnstiles were reengineered to reject tokens, though they were accepted on buses for a grace period, along with the payment of an additional 50 cents.

Today, some transit system sell tokens as one of several ways to purchase fares (for example, stored value fare cards, cash); examples include Toronto, Los Angeles, and Paris. Others have phased out tokens in a manner similar to New York City. For instance, the Maryland Transit Authority, which serves Baltimore, ceased selling tokens in June 2003 and ceased accepting them one year later.

As in New York, the switch from tokens to electronic cards was accompanied by a fare hike; unlike in New York, passengers in Baltimore were allowed to continue to use the tokens for a grace period without depositing additional cash in the farebox.

Passes and Multiple-Use Tickets

Many transit systems offer passes good for unlimited rides within a certain time period, typically one day, one week, or one month. These passes may be simple cards to be displayed to the driver, booth clerk, or fare inspector upon entering the system or upon request. With this system, passes for different periods must be visually distinctive (for example, the March fare pass could have a different color from the February fare pass) to prevent people from easily using a pass that has expired.

Pass systems have proven popular in many cities where they have been introduced. For instance, two months after Atlanta, Georgia, introduced a monthly pass in 1979, the pass was being used by 12.7 percent of passengers and on 17.8 percent of trips; riders polled about their reasons for purchasing the pass cited savings (56.2 percent) and convenience (28.4 percent) as their primary reasons.

After New York City introduced unlimited-ride passes in 1998 (seven-day and 30-day cards) and 1999 (one-day cards), as well as free transfers, subway ridership went up 6.6 percent on weekdays and 11.5 percent on weekends, and bus ridership went up 26 percent on weekdays and 27.2 percent on weekends. When London introduced a Travelcard pass good on the Underground (subway) and bus system in 1983 and 1984, an estimated 20 to 33 percent increase in passenger miles traveled was attributed to the Travelcard.

Pass systems have also been used to promote the use of public transit by groups of people, such as students at a particular school or employees of a particular company; often the school or employer offers the passes at a discount to limit the number of people driving to work or school. These programs have often proven popular.

The University of Washington in Seattle, for example, began offering a discounted unlimited-ride pass (the U-Pass) to employees and students in 1991, in combination with increased parking fees on campus. After one year, vehicle trips to campus were reduced by 16 percent, and transit ridership was increased by 35 percent.

Multiple-use tickets are good for a fixed number of rides and are often sold at a discount compared to buying the same number of rides individually; for instance, the Long Island Rail Road (New York) offers a 10-trip ticket that costs less than buying 10 individual tickets. Paper multiple-use tickets are usually punched or marked by the conductor each time they are used, making it easy to see how many fares are left on the ticket; stored-fare cards may also be good for a specific number of rides, in which case each use is recorded electronically. Some transit systems allow multiple-use tickets to be shared among individuals (for instance, several people traveling together), while others restrict use to only one traveler.

Stored-Value Cards

Many transit systems have adopted the use of electronic, stored-value cards, using plastic cards similar to credit cards. In this system of fare collection, the user buys a card worth a certain amount (for example, \$20), and the cost of a fare is automatically deducted by a card reader each time the card is used. Many systems also allow people to add money to existing cards, and may offer a bonus for putting a certain amount of money on a card (for example, a \$2 bonus when putting \$20 on the card).

Some stored-value card systems require direct contact of the card with the card reader (for example, swiping the card through a narrow slot), while others use radio frequency identification (RFID) technology to communicate with the card reader by high-frequency waves. RFID cards and their readers have the advantage that they are not subject to wear and tear as much as the cards that require contact and do not require the user to swipe the card at a particular speed in order to be read.

Smart cards allow transit systems to collect information about the number of riders entering the system at particular times and locations, information that may be used to plan to improve service. However, because they allow for the collection of information about when and where particular cards have been used, they also have raised privacy concerns. Such systems make it theoretically possible to identify where a given person (or, actually, a given transit card) was used at a particular time.

In fact, such information has been used to defend individuals against criminal charges by demonstrating that they were not near a crime scene at the time of a crime. Encryption is generally used in smart-card systems, but the fact that card-use information is gathered and stored in a central location, where it could be theoretically linked to other data, is a matter of concern for some people.

One concern with RFID technology is that the information stored on an RFID card can be altered by someone with sufficient technical knowledge. In 2008, three students from the Massachusetts Institute of Technology (MIT) wrote a paper demonstrating how to “hack” or reprogram the RFID fare cards used by the Massachusetts Bay Transportation Authority (MBTA) in order to obtain free rides.

The MBTA sued to stop the students from presenting their paper at a conference in Las Vegas, Nevada, arguing that it would violate laws regarding computer fraud and that MBTA authorities should have a chance to review the security flaws in the system before those flaws were made public. However, the students claimed that they would have withheld key information in their talk, and that they should be allowed to present the paper as a matter of academic freedom; a U.S. district court judge agreed with the students, ruling that presenting an academic paper would not violate computer fraud laws.

Advantages of Stored-Value Cards

Implementing a stored-value card system is a major expense for a transit system but offers such advantages that many systems are converting exclusively to stored-value cards, as well as adding them as an option for fare payment.

One obvious advantage of stored-value fare cards, from the point of view of the transit system

management, is that fares can be easily changed without the need to issue new tokens. Instead, when a new fare structure is implemented and the equipment updated, the correct amount for the new fare will be automatically deducted from an individual's farecard. Passengers are also less sensitive to price changes when using stored-value fare cards, as opposed to paying a cash fare.

Another advantage of stored-value fare cards is pricing flexibility. Transit system pricing has multiple competing goals, including raising revenue, promoting use of the transit system, charging riders a fair amount based on their circumstances, and shifting ridership from peak periods of usage to less crowded periods. One strategy to achieve these goals is differential fare pricing. Examples of this include charging different fares at different times and days, for different lengths of trips, for different classes of riders (for example, students, senior citizens, handicapped people). While these goals can be achieved with other methods of fare collection, the use of stored-value electronic fare cards makes them particularly easy to achieve.

Stored-value cards facilitate transit system integration, including transfers among different types of transport (for example, subway to bus). Although a transit system using cash or tokens can offer transfers among lines or modes of transit by the use of paper transfers, the process is simplified with stored-value cards that can register a transfer (including checking for time or route limitations) without subtracting further money from the card.

Stored-value cards can also check for valid transfers (for example, that the allowed time period has not expired, and that transfer is allowed between the routes in question), while paper transfers require a system of visible coding that may include the time, line, and direction for the trip on which the fare was paid, but the driver or fare collector must inspect each transfer visually to see if it is valid.

Stored-value cards also offer more flexibility in terms of offering unlimited-ride cards, usually for a period of time such as one day, one week, or one month. While this can also be accomplished by issuing a pass that the passenger displays to the bus driver, train conductor, or token clerk, electronic unlimited-use passes have the advantage of automating the process. Stored-value cards also allow unlimited-use passes to be sold for any period, not just a calendar week or month.

For example, a 30-day pass could be good for any consecutive 30-day period, or a day pass for any 24-hour period.

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See Also: Bus Rapid Transit; Commuter Buses; Commuter Rail; Student Transport; Subway Systems; Transit Fares.

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Transit Finance

Although most transit systems charge fares to riders, these fares often do not provide sufficient revenue for the system to remain in operation. For this reason, a variety of other financing sources are used, including federal and state general tax revenues, specific state or local revenues (e.g., a gasoline tax), and/or the issuance of various types of bonds. Some transit systems have also tried different pricing strategies to increase revenues, and local governments have entered into public–private partnerships as an additional way to finance aspects of their transit systems.

History

Many transit systems that are now primarily or entirely public began as private, for-profit systems, with government involvement initially limited primarily to regulation. In fact, in 1945 only 2 percent of transit systems and 16 percent of transit vehicles in the United States were publicly owned; by 1985, the public share had increased to 30 percent of the systems and 80 percent of the vehicles.

Loss of ridership played a role in the shift to public ownership. While transit use peaked in the United States in the 1940s, with an annual ridership around 24 billion nationally, by 2000 ridership had fallen to below 9 billion. The loss of ridership was reflected in declining revenues for transit systems and motivated the search for other sources of funds. As late as 1960, fares provided most of the operating revenues for transit systems, but this share declined over the next several decades to 54 percent by 1975 and 36 percent by 1988.

The Urban Mass Transportation Act of 1964 provided federal assistance to upgrade transit equipment, in part because deterioration of existing transit systems raised fears that they might cease to operate at all. At about this time, many cities created public transit authorities, purchasing the assets of private transit companies and operating them with the services and fare structures decided by governmental or quasi-governmental decision makers.

In 1974, the federal government began offering operating assistance as well, and by 1988, fares only paid about one-third of operating costs (36 percent), with the rest coming from state and local governments (52 percent), the federal government (6

percent), and other operating revenues (6 percent). However, federal support for public transit began to decline in the early 1980s, and the difference was primarily made up by state and local governments, using a variety of revenue sources including sales taxes, fuel taxes, property taxes, general tax revenues, and the proceeds of lotteries. In general, non-urbanized transit systems receive a higher level of subsidy than do urban systems.

The amount of transit operating expenses that should be covered by fare revenues is a matter of debate. At one extreme, some argue that fares should be high enough to cover all expenses, a solution that is neither practical nor equitable in most areas, as other forms of transportation, including private automobile travel, receive numerous subsidies. On the other extreme, some argue that public transit should not collect fares at all—instead it should be offered as a free public service.

While free or nearly-free service has been offered in some systems (for example, Moscow and Mexico City), this has not proven sustainable other than in limited cases, such as fare-free zones in central business districts or transit services provided around airports, when a primary aim of the transit service provided is to reduce automobile travel and relieve congestion.

Fare Revenues

Nationally, the average portion of a transit systems' expenses paid through farebox recovery from 2002 to 2004 was 35 percent, with a range from 9 percent (Austin, Texas) to 60.6 percent (Washington, D.C.). Internationally, only a few transit systems are self-supporting, including those of Singapore and Hong Kong. The estimated rate of subsidy for Europe is 44 percent, and the rate for Canada is 56 percent.

Aside from arguments about fairness (people with lower incomes, the elderly, and the disabled may depend on transit more than high-income, working-age, able-bodied people), the relationship between fares and revenues is not always straightforward. Although it may seem obvious that raising the fare should increase revenues, this is not necessarily the case, as ridership may decline enough to offset the additional revenue gained from each fare.

Although the price elasticity of demand for transit services varies across many conditions, the

Simpson & Curtin formula is a commonly accepted method to calculate changes in aggregate ridership expected with changes in price as

$$Y = 0.80 + 0.30X$$

Where Y = the percent loss in ridership after the change in price compared to the ridership before the change, and X = the percent increase in fare compared to the prior rate. By this formula, a 10 percent increase in fares would result in a 3.8 percent decrease in ridership, because

$$Y = 0.80 + 0.30(10) = 3.8 \text{ percent}$$

Studies of fare changes in particular cities have found this to be a reasonable average estimate, although bus elasticities are generally about twice as high as rail and subway transit elasticities, possibly because other alternatives such as driving an automobile are more easily substituted for bus service, and because urban rail transit may offer advantages such as speed and convenience that cannot be replicated by other forms of transit. Other factors that have been found to be related to fare elasticity include the population of the service area and time of day (peak versus off-peak travel).

One method some transit systems have adopted to increase revenues is to reduce rather than raise fares for selected groups by offering deep discounts (for example, staff members and students at a university).

Characteristics of typical deep discount group pricing (DDGP) programs include offering a pass good for unlimited rides for all members of a group at steeply discounted pricing (for example, 40 percent to 94 percent off a comparable pass available to the public); some also include guaranteed-ride-home programs (offering alternative forms of transportation if an employee works beyond the transit system operating hours).

DDGP programs in Denver, Colorado; Berkeley, California; and the University of California, Berkeley, were found by one researcher to be generally successful in increasing operating revenues; specifically, he found that DDGP programs consistently resulted in higher revenues per board (compared to the systemwide average) or higher total revenues for the transit system compared to similar markets without a DDGP program.

Tax Revenues

One important source of funds for transit systems is federal subsidies, which rose substantially for several decades beginning in the 1970s, then declined. Measured in constant 2000 dollars, federal transit subsidies in the United States rose from \$4.5 billion in 1975 to \$12.3 billion in 1992; by 2006, the federal subsidy had dropped to \$8.1 billion. However, the 1974 program that offered federal operating subsidies to local transit systems required a 50 percent match from other sources of funding (including fare collection and state and local funding), so transit systems have for decades needed to find ways to raise funds independent of federal subsidies. In addition, almost half of federal funding for transit goes to just a few states: New York, California, Massachusetts, New Jersey, Pennsylvania, Illinois, and Maryland.

In 2006, almost all (94 percent) states provided funding for public transit. Combined, the states provided \$11.1 billion in transit funding, more than twice as much as the \$4.8 billion provided by the states in 1995. In 2006, the most common sources of state revenues to support transit included gas taxes (19 states); the general fund (12 states); bond proceeds (10 states); taxes on rental cars and motor vehicle sales (10 states); fees for automobile registration, titles, and licenses (10 states); and general sales taxes (9 states). However, as with federal funding, the bulk of state funding for transit is provided in just seven states—New York, California, Massachusetts, New Jersey, Pennsylvania, Illinois, and Maryland—which together received \$7.6 billion in funding in 2004, compared to \$1.7 billion for the remaining 43 states and Washington, D.C. Transit ridership often increases during a recession or other long period of economic stagnation and/or unemployment, while tax revenues decrease during such times. This fact has motivated many transit systems to seek a variety of sources of funding. In addition, concerns about air pollution, health, and quality of life have also created broad interest in finding ways to make public transit financially stable, and in some cases to increase transit services as well.

Numerous options exist to finance public transit, each offering both advantages and disadvantages. General obligation bonds are issued by a government entity, and repaid from general tax revenues; they can offer lower interest rates (and hence are a cheaper way to borrow money) than some other types of bonds because they are backed by the full

faith and credit of the issuing body. However, the bonds must be paid back even if tax revenues are lower than anticipated, so other programs may have to be cut to compensate.

Revenue bonds are repaid by specific revenues (for example, the fees generated by a parking facility whose construction was financed by the bonds), and thus are riskier and generally must offer higher interest rates than general obligation bonds; however, they are less risky for the government because the bonds are not backed by general revenues.

Tax increment bonds are based on the principle that investment in transit generally results in higher property values, and thus increased property taxes; this is advantageous in that some of the benefits of the transit construction are used to pay back the bond, but risky in that the expected increase in revenues is not guaranteed.

GAN (Grant Anticipation Note) bonds borrow against the expected future value of federal transit funding and apply only to metropolitan areas with populations of 200,000 or more. Because of the predictability of federal funding (which is determined by a formula), these bonds have a low interest rate, but this type of financing means that future funds are being spent before they are received and will thus not be available to carry out other projects.

Public-private partnerships are another way to fund public transit. In this system, a private entity carries out specified aspects of a transit project after raising the capital necessary to complete the project, and the entity is allowed in return to collect user fees and/or receive payments from the government. Public-private partnerships allow government to shift some project risks onto the private entity, but it is generally a more expensive way of raising revenue than issuing bonds. In addition, the government cedes some control over the project to the private entity.

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See Also: Benefit-Cost Analysis of Transportation; Federal Transportation Policy; Privatization of Public Transit; Transit Fares; Transit Fares, Elasticity of Demand of; Urban Mass Transit Act of 1964.

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Transit Industry, Economics of

Revenues collected from the fare box are never enough to cover the operating costs of a transit agency's services. The percentage of operating costs that is covered by fare revenues is commonly known as the "farebox recovery ratio." This ratio can be measured, for example, by route, by type of service (local, express, etc.), by mode (bus, light rail, heavy rail, etc.), or for an entire system.

In some cases, it may be possible for some routes or service types to generate enough in fare revenue

to cover the operating costs associated with those services; however, in general, no transit agency in the United States collects enough in fares to pay all of its operating costs, much less capital costs. As a result, a transit system's farebox recovery ratio is less than 100 percent.

On average, transit fares tend to cover only approximately 25 percent to 35 percent of all operating costs. To pay these costs, transit agencies must generate other types of revenue and also must rely on subsidies at the local, state, and/or federal levels.

Transit Operating Costs

To put services on the street, transit agencies must pay operating costs associated with general administration and maintenance, as well as the actual operation of the transit service. Administrative costs include functions such as office management, human resource administration, transit service development and planning, market research, legal services, customer service, finance and accounting, and other data processing functions. Transit agencies often try to keep administrative costs low so that as many resources as possible can go toward maintenance and operation of the service.

Maintenance expenses can be generally classified as those relating to vehicle maintenance or to non-vehicle maintenance. Vehicle maintenance costs are those costs directly related to maintaining the transit vehicles for service, including inspections, maintaining vehicle maintenance records, compiling vehicle performance data, training maintenance personnel, vehicle repairs, and other general vehicle servicing. Nonvehicle maintenance costs are those related to maintaining transitways, facilities, buildings, grounds, and equipment, as well as the related supervision, clerical support, and training.

The largest share of operating costs is associated with the actual operation of the transit services. Within this category, the largest element tends to be the cost of the transit vehicle operators, in salaries and benefits. Other costs in this category include transit operations administration and support, vehicle movement control (also known as dispatch or transit vehicle traffic control), activities associated with the scheduling of transit service, activities related to ticketing and fare collection, and system security.

While there is pressure to keep administrative costs low, transit agencies are always actively trying

to find ways to keep all operating costs down. It is a challenge for the agencies to offer the types of services demanded in their communities within the funding constraints from fare policy and government subsidies. Trade-offs must often be made, for example, between offering more service covering a larger geographic area and offering service that is more concentrated in a smaller geographic area but more intensive (that is, more frequent service and/or with longer operating hours, called the service span).

Fares and Other Directly Generated Revenue

To take a trip on transit service, passengers must pay a fare. Transit fares may vary by mode or type of service, by time of day, by type of passenger, or by other factors. Sometimes, passengers must also pay an additional fare to transfer to another route or type of service (known as a transfer fare).

Fares can be paid on a per trip basis in cash, or passengers can usually elect to purchase a prepaid pass from a range of options, including passes that are valid for a given number of trips and passes that are valid for a certain length of time (such as daily, weekly, or monthly). Typically, passes provide extra value to the passenger by lowering the average fare paid per trip.

Other types of passes offered by transit agencies include discounted passes for students, the disabled, and the elderly; people in these groups also tend to pay a discounted per trip fare. Some transit agencies may allow passengers in certain groups, such as the elderly or students, to ride free.

Agencies that operate in cities with universities sometimes have an agreement with the university to allow students to ride free in exchange for a bulk payment, usually comprised of funds that originate from student fees. In some cases, a transit agency may decide to operate all or part of its service fare free. Clearly, the fare policy of a transit agency will have a significant impact on the total amount of fare revenue it generates and, subsequently, its farebox recovery ratio.

In addition to fares, transit agencies often look for other ways to generate revenue on their own. One common way that transit agencies generate additional revenue is through displaying advertising materials on transit agency vehicles and/or property (such as at stations or on stops/shelters). Other directly generated revenues may result from park-and-ride revenues, interest income or

investment earnings, concession sales at stations or on vehicles, revenues from leasing parking facilities or portions of stations or other facilities for private use, and donations or other private grants.

Sometimes, the transit agency may be designated as an independent political entity or special taxing district, which provides the agency with the authority to directly levy taxes, such as property, gas, or sales taxes. These types of taxes are considered dedicated to transit at their source.

Local and State Revenues

As stated previously, revenues from fares usually cover approximately 25 to 35 percent of the average U.S. transit agency's operating expenses. While agencies can generate additional revenues directly, there still remains a need for additional subsidies. Local and state governments often provide additional revenues for the operation of transit services. At the local level, a government entity may elect to provide a subsidy to the agency out of the entity's general revenue fund. Other options at the local level include revenue from income taxes, gas taxes, sales taxes, property taxes, hotel taxes, utility fees, and parking fees and fines, among others. In contrast to taxes directly levied by a transit authority, these other local taxes are not necessarily dedicated to transit at their source.

Many state governments also provide funds for the operation of transit services. Such funds may originate from taxes (for example, sales, income, or gasoline), vehicle registration fees, employer or payroll taxes, lottery or casino revenues, vehicle leasing and rental fees, and toll revenues, among others. It should be noted that the lists of potential local and state funding sources provided above represent commonly used funding types and are not exhaustive. Transit agencies often work with their local and state governments on various strategies for funding public transit services.

Federal Revenues

The federal government has a role in funding the operation of public transit services in the United States. Transit agencies can apply for a range of federal grants to fund portions of the capital requirements for transit services, as well as the operating costs.

Currently, two major sources of federal transit assistance include the Federal Transit

Administration (FTA) Urbanized Area Formula Program (§5307) and the FTA Other than Urbanized Area Formula Program (§5311). These two funding programs provide funds for capital projects planning, capitalized operating assistance (for example, preventive maintenance), and operating assistance in urbanized areas (UZAs) with populations smaller than 200,000 and in non-UZAs with populations less than 50,000. It should be noted that recipients of these grants are required by statute to submit reports to the National Transit Database (NTD). Data from the NTD are available publicly and represent a good, comprehensive source for transit statistics and other information.

In addition to funding programs available from the FTA, transit agencies may also be eligible for funding from other U.S. Department of Transportation programs. In recent years, however, the amount of funds available at the federal level for transit operating assistance has declined, resulting in a greater reliance on funds from the state and local levels. In addition, transit agencies increasingly seek out other new, innovative ways to fund their services.

Innovative Cost and Funding Strategies

Recent economic conditions have found transit agencies in situations where they have had to increase fares, cut service, or both. Declining shares of federal transit operating assistance, budgetary pressures at the state and local levels, and increasing labor, fuel, and other costs have resulted in the need for transit agencies across the country to look for other ways of funding transit services.

In the transit industry, much research has been done on innovative funding strategies and, in addition, transit agencies can learn from other agencies' experiences with novel ways to keep costs down and generate additional revenue.

One way that some transit agencies have been successful in reducing costs has been by contracting out some or all of their services to private transportation providers. In many cases, the public agency still maintains control of and plans the service, while the private provider is responsible for the actual operation of the service. There are many factors that a transit agency must consider in determining whether privatizing all or part of its services will be beneficial and result in the expected cost savings.

A common strategy for generating new revenue involves the creation of public-private

partnerships, which essentially allow the public transit agency to leverage private resources to better achieve its objectives. An example is when the public transit agency and one or more private organizations collaborate on the joint development of a transit station or other facility. Other examples include situations where entities from the private sector assume a larger role in the planning, financing, construction, operation, and maintenance of public transit facilities.

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See Also: Transit Cost Allocation Models; Transit Fares; Transit Finance; Transit Performance Monitoring and Evaluation; Transit Systems Analysis.

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systems, and a range of other types. The common thread is the transference of and access to information that helps managers, administrators, workers, customers, funders, and planners make good decisions about the transit network appropriate to the manner in which they interact with it and with each other. Transit information systems also facilitate communication between multimodal transit networks, as well as between the networks and their external partners, whether suppliers, oversight agencies, or other entities.

Passenger Friendly

Passengers benefit by being able to access transit information through a variety of places, modes, and times. Each time a passenger seeks to plan a trip, check on route conditions, determine a fare, or gain other information, the administrators and operators responsible for the transit information system have an opportunity to deliver a customer benefit. When they realize such benefits, customers are more likely to enjoy increased service quality satisfaction—the single most important factor in improving all other ridership metrics.

Passenger information systems stem from origins as simple painted signs and printed schedules, supplemented by public address speakers, visual cues at stations and on rolling stock, and occasionally in mailings and public awareness advertising campaigns. In the contemporary sense, all of these modes are electronic in form and, increasingly, digitally enabled. Destination indicator boards within subway cars, on trains, and in buses, as well as on station platforms, can offer a route map showing active and inactive destination stations; this essential information can be augmented with data such as estimated arrival times, time to next station, next available service, and the next connecting service.

LED illumination has been widely adopted for these devices, boosting reliability and readability while conserving electricity. These display boards can be used in conjunction with digital voice messages and, in some of the more advanced installations, can be linked to wireless Internet service.

Ideally, these systems provide passengers with real-time information, although versions representing most of today's installed base provide only standard, preprogrammed station-to-station announcements. Still, the majority of these systems

Transit Information Systems

Transit information systems can include passenger information systems, dispatcher and driver communications and information systems, network monitoring models, internal auditing and planning

are complemented by some means, generally auditory, of delivering such information as reasons for delay, the cause of a disruption, and any emergency or service-change updates.

Next Phases

Stationary transit information devices, such as interactive kiosks, can provide an extra measure of customer satisfaction during times when they are not being actively transported on the network. A system installed in 2012 in New York City by the Metropolitan Transportation Authority, for instance, features On the Go! kiosks that show-case route maps, line status, and ancillary trip planning information such as entertainment and cultural attractions by neighborhood. All of this information is produced in a visually stimulating format. Touch screen technology and colorful, large-aspect screens have made the pilot project a notable success, one that is being expanded.

There exists a multitude of opportunities to extend the reach and function of such installations. A new generation of self-service ticket kiosks, for instance, could double as travel information centers. Beyond simply enabling people to purchase a fare or refill a fare card, the enhanced kiosk could provide travel advisories in real time and suggest alternate means and routes for the passenger to reach destinations.

Radio frequency identification (RFID) systems, which use a barcode recognition technology, can already handle transactions in conjunction with smart cards. These can be tailored to provide personalized information upon recognition of the individual who is presenting the card. RFID systems are limited to very short distance scanning pickup—dubbed near-field communications, or NFC—but through constantly innovating “tag” technology, the sophistication of this data transfer platform is being leveraged to provide for imaginative new applications.

A trial in the Bay Area Rapid Transit (BART) system in San Francisco employed RFID hardware and protocol to enable commuters and other travelers to purchase train fares at BART subway stations equipped with turnstiles that read the RFID chips embedded in their cell phones. This is an extension of RFID-enabled smart card technology that opens the gate to information exchange beyond a simple fare transaction. BART officials have considered



Electronic information systems provide arrival and departure times as well as information about delays and disruptions. The same information can be delivered to passengers through the Internet, mobile phones, or self-service touch screen kiosks.

building out the system with such features as reward programs and linking to retailers, among other features the system could enable. This type of system is a variation of versions that are in much wider use in some Asian metropolitan areas, such as Hong Kong.

Network Information

Nearly all transit units, or vehicles—trains, trams, subway cars, buses—feature communications equipment in the driver cab. Usually these installations include straightforward telephone or radio connections to dispatchers, as well as internal public address systems that may have alternate channels for exchanges with other transit personnel such as conductors. The equipment typically includes a transmitter built into the vehicle.

Drivers on some transit vehicles also deploy pre-recorded digital voice messages for the benefit of the passengers. On occasion, they add their own live notifications in order to provide actual route condition or vehicle situation information. More frequently, they use the internal public address system to manage passenger behavior and make suggestions and announcements.

There are also emergency transmission systems. Some bus drivers, for example, can activate a type

of silent alarm that combines a wireless alert beacon with an emergency message displayed on the external visual readout panels, such as “Call 911. Emergency.” This type of alert can gain the assistance not only of central control dispatchers but also, potentially, of passersby, who can help guide emergency responders, thus cutting response time.

Dynamic Mobility

Prototypes of far more advanced information systems are in various stages of research and design. For example, the Intelligent Transportation Systems Joint Program Office of the U.S. Department of Transportation’s Research and Innovative Technology Administration (RITA) is engaged in various development projects it manages under the rubric of dynamic mobility applications. The goal, according to RITA, is

making surface transportation safer, smarter, and greener by leveraging wireless technology capabilities in an interoperable communications network environment to provide safety, mobility, and environmental benefits to the transportation community and the traveling public.

RITA has oversight for research projects that are testing dynamic mobility software applications to allow traffic managers to better anticipate transit system problems, use predictive modeling to aid decision making, and monitor impacts of decisions in real time by way of dedicated short-range communications and related wireless methods.

To test such ideas, various types of probes, sensors, and transmitting nodes are embedded in vehicles tied together through existing networks. They are then linked via the new data exchange systems. Many such RITA programs are still in the stage of defining metrics for single-mode and multimodal performance and at the same time identifying highest-value public sector applications to prioritize.

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See Also: Advanced Traveler Information Systems; Automatic Terminal Information Systems; Bus Information Systems; Geographic Information Systems in Transportation; Information Technologies and Transportation; Intelligent Transportation Systems.

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Transit Lines/Networks

There are many ways to organize a transit system, and the choice of how to do it is made by balancing numerous factors, including pre-existing travel networks, varying demands for services in different parts of a region, efficiency and economy, and comprehensibility to users. Among the most common types of organization in use for transit systems are rectangular grids, radial grids, and polycentric networks.

Grid Systems

The rectangular grid system, with streets of uniform width regularly spaced and laid out parallel or at right angles to each other, is one of the oldest city

layouts known. There is archaeological evidence that it was used in ancient Egypt, in the Babylonian empire, in China, and in ancient Mexico City, among other places.

Many American cities were also laid out in a grid pattern, or the grid pattern was imposed at some point in the city's development. For instance, in New York City, the Commissioners Plan of 1811 imposed a grid pattern on the island of Manhattan north of Houston Street, while the older streets south of Houston retained a much more irregular and random pattern. When public transportation routes began operation in cities constructed on the grid layout, they naturally followed those patterns as well.

Rectangular grid patterns have many advantages. For one, they offer good transportation service across the grid if riders are allowed to transfer between lines, because no point in the grid lies too far from either a north-south or east-west line. This means that no point in the grid is inherently privileged over any other when it comes to accessibility by public transit, and this is particularly beneficial if an area has multiple key areas of activity.

Grids also work best if the lines are anchored by major destinations at their endpoints, because that means there will be lots of people riding to the end of the line. Grids are also intuitively easy to understand, although they have the disadvantage that they work best in relatively flat regions. San Francisco is a famous example of a city that laid out its roads on a grid system without considering the underlying topography; the result was many roads running up and down extremely steep hills, a reality that motivated the development of the city's signature cable car system.

Another type of grid is the polar or radial grid, which centers on a single area (for example, the downtown area of a city) with transit lines laid out in concentric rings around this central area; straight lines cross one another throughout the central area, creating the appearance of a spider web. With this system, areas near the city center are close to one or more transit lines, while areas farther away from the center have a higher probability of being farther from any transit line.

This system has advantages if the central point is truly primary in the travel patterns of the majority of transit users in the area, if areas farther away from the center are less likely to be visited

by people using public transportation, and if it is assumed that alternate transportation (for example, an automobile) is an available option for those living away from the city center. This layout is less intuitive than a rectangular grid but increasingly familiar because many U.S. urban areas (for example, Washington, D.C., and greater Boston) have roadway patterns with this design, in which a beltway or ring road surrounds the city or metropolitan area and a second system of roads leads to and from the city center.

Different transit network designs may favor different types of riders, based on their needs and resources. For instance, higher-income residents may be best served by a radial grid system, in which transit lines are organized primarily to transport people from widely spaced suburban stations into the downtown area, with the greatest amount of service provided during rush hour when commuters are coming to or going from their downtown jobs.

Riders of this type of service may well own one or more automobiles that they can use when they need to go somewhere other than where the transit system goes (for instance, to do their shopping or to visit their child's school) or to go somewhere when the transit system is not operating (for example, to go out in the evening). Lower-income residents may not have their own personal transportation and hence will rely on the public transportation system for all their transportation needs. Such riders are often better served by a rectangular grid system, which provides more blanket coverage of an area and does not prioritize one area over another.

Polycentric Route Networks

In a polycentric network, several areas in a region are considered centers. Centers are often defined in terms of employment, so a center has either a minimum number of jobs, or a job density higher than surrounding areas or higher than a designated threshold of jobs. However, one of these centers could also be a place of government, an educational complex, a convention center, or similar destination where large numbers of people travel regularly.

This type of organization is typical of many American suburbs, and Los Angeles County is often cited as a prime example of a polycentric metropolitan region, because it has multiple job centers, business districts, government centers, and



This photo of the greater metropolitan area of Phoenix, Arizona, taken at night from the International Space Station in low Earth orbit, shows the city's north-south grid layout as outlined by street lighting. Grand Avenue, a major thoroughfare lined with development, transects the grid and provides a transportation link from northwest to southeast. Grids are an ancient city design that work well in flat regions, but variations such as polycentric networks have been found to work better in some suburban areas.

attractions spread out across a wide area and separated by residential areas.

A grid system can work well in a polycentric region because it allows approximately equal access to all parts of the grid. However, the grid layout may be wasteful if too many resources must be expended in providing access to areas of low density and priority.

A polycentric or multide destination route network is an alternative to the grid in areas in which multiple centers require service, and the transit system is arranged with transfer points allowing people to switch from one line to another. Between 1983 and 1998, three transit systems that switched to a polycentric route network all had better performance than most traditional polar grid networks, including increased ridership and lower operating costs per passenger mile. Researchers interpret these results as suggesting that polycentric route

organization may be the best way to serve suburban areas with public transit.

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See Also: Airports Hubs; Bus Routes; Commuting; Street Design/Patterns; Transit Centers.

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Transit Management and Operations

Transit management is an ongoing process that encompasses development, implementation, evaluation of budgeting, service deployment, performance measurement, and other components of the operation of a transit system. In the largest sense, a transit system includes all vehicles, public and private, that move goods or people from one place to another whether by land, air, or sea.

In practical terms, particularly since the advent of the automobile age, "transit system" has commonly referred to public systems that provide scheduled services on fixed routes via modes that include some combination of bus, trolleybus, vanpool, jitney, and paratransit service; heavy rail, light rail, commuter rail, automated guideway transit, inclined plane, cable car, monorail, and aerial tramway; and passenger-only and vehicle ferries, and water taxis.

Transit managers oversee transit vehicle fleets and coordinate operations with other transportation services. The responsibilities of transit managers include not only the functioning and maintenance of transit vehicle fleets but also such tasks as supplying customer information; ensuring communications between transit departments; checking compliance with federal, state, and local regulations; and collaborating with emergency response

services, traffic management systems, and other operating entities as necessary. The transit manager must be able to make decisions in such areas as strategic planning management, labor relations, maintenance planning, administration, financing, marketing, and fare policy.

Changes in Ownership of Public Transit

Public transit has a long history in the United States, beginning in 1852 with New York City's horse-drawn streetcars. Electric streetcars were introduced in 1888, and mass transit ridership steadily increased through the end of the 19th century and into the beginning of the next. Although the Staten Island Ferry became the first public takeover of a private transit company in 1905 and Monroe, Louisiana, boasted the first municipally owned street railway in 1906, most transit companies were privately owned in the first decades of the 20th century.

That situation changed when the first major decline in use came in the 1930s during the Great Depression. Early in that decade, electric companies, who had acquired streetcars for nonpayment of bills, became major transit providers, but their reign was brief. The Public Utility Holding Company Act of 1935 (PUHCA), among other provisions, limited registered holding companies to business activities directly related to the conduct of their utility operations, forcing them to abandon their interests in transit companies. Congress repealed the PUHCA in 2005.

Transit ridership reached 23.1 billion in 1946, but by 1950, 60 percent of American households had a car. A decade later, with growing numbers of American families living in suburbs, three-fourths of American families owned at least one automobile. The Federal Aid Highway Act of 1956 authorized \$25 billion over a 12-year period to pay for the National System of Interstate and Defense Highways. National mobility was becoming a reality, but Americans were traveling in cars rather than by bus and rail.

The Housing Act of 1961 granted cities \$75 million to purchase failing transit companies, and communities across the country began public operations. By 1972, transit ridership dropped to a low of 6.5 billion trips. The National Mass Transportation Assistance Act of 1974 for the first time authorized the use of federal funds for transit operating assistance, but transit systems were forced

to compete with highways for funding until the Intermodal Surface Transportation Efficiency Act of 1991 earmarked money for transit and pushed multimodal services.

Transit Vehicle Fleets

A key component in transit management and operations involves the scheduling, maintenance, and performance monitoring of fleet vehicles. Transit trends in the United States have shown consistent long-term growth since the early 1970s, although growth by mode is irregular. Transit customers using bus services have grown only about 17 percent over the past four decades, whereas use of heavy rail and light rail has more than doubled during the same period. In 2010, United States transit systems had a combined total of 174,425 vehicles available for service.

Bus service is the most heavily used transit service, accounting for more than half of transit riders. During peak service, more than 66,000 buses were operating in U.S. transit systems in 2010. Slightly over a third of transit riders used heavy rail services with 11,510 vehicles during the same period. But heavy rail service is concentrated in large urban areas, while many smaller cities and suburbs offer bus transit. However, the largest fleet of transit vehicles belongs to the demand-response service with 68,621 vehicles, and this mode is utilized in both urban and rural areas.

In 1990, the Americans with Disabilities Act (ADA) was signed into law, mandating that services and facilities be accessible to persons with physical and mental disabilities that substantially limit one or more major life activities. The ADA covers accessibility to employment, public accommodations, government services and facilities, transportation, and telecommunication. Unlike most transit regulations, adherence to the provisions is not related to receiving local, state, or federal funds for projects. The ADA is civil rights legislation, and the U.S. Department of Justice, not the Department of Transportation, has the responsibility of ensuring compliance.

Noncompliance leaves a transit system vulnerable to lawsuits on behalf of persons with disabilities. By law then, in all areas served by regular route transit service, accessible demand-response service must be provided to persons with disabilities that render them unable to utilize fixed-route

service. Demand-response vehicles that travel on roads and streets but take passengers directly from their origins to their destinations, typically vans, have been the common response to this legal requirement. Often the service is also available to all riders, and some areas operate the service in lieu of fixed-route service during late-night and weekend hours. Since the service was begun only after the passage of the ADA, its growth rate is not comparable to that of longer-established services, but the number of fleet vehicles devoted to the service attests to its popularity.

Whatever mode or combination of modes a transit system uses, transit managers are responsible for preventive and corrective maintenance of the fleet vehicles. In 2008, the Federal Transit Administration (FTA) in conjunction with 14 public transportation providers and state departments of transportation determined that \$10.7 billion would be needed to bring all transit modes nationally into the desired state of good repair (SGR), a state in which all preventive maintenance and rehabilitation needs are addressed and no capital asset exceeds its useful life.

Heavy rail and motor bus vehicles topped the list of priorities, with heavy rail stations, systems, and guideway components and bus maintenance facilities falling next in line. The group found that the actual retirement age of buses, for example, generally exceeded FTA minimums because funding was not available for replacement vehicles. The analysis emphasized that vehicles in less than optimal condition can increase problems such as disrupted service, maintenance costs, and slow speed zones.

The asset management approach that was practiced by many of the most effective transit systems in the 2008 study became standard in 2012 when Congress passed the Moving Ahead for Progress in the 21st Century Act (MAP-21), a funding and authorization bill to govern federal surface transportation spending, which required the FTA to establish a national transit asset management system that, through regulation, will define "state of good repair," set objective standards for measuring the condition of capital assets (including equipment, rolling stock, infrastructure, and facilities), and establish performance measures for state of good repair, under which all direct and indirect recipients of FTA grants will be required to develop a transit asset management plan and use an asset

management system to develop capital asset inventories and condition assessments, and to report on the condition of their system as a whole, including any change in condition since the last report, targets set under the performance measures, and, progress toward meeting those targets.

Capital and Operating Expenses and Funding

Of the \$55.6 billion spent by the transit industry in 2010, almost 68 percent of it was spent on operating expenditures. An additional \$17.8 billion was spent on capital investments (largely purchases of vehicles and equipment, and the development of infrastructure and supporting facilities). Operating expenses are measured by function, such as vehicle operations, vehicle maintenance, non-vehicle maintenance, and general administration. Object measurement refers to the grouping of expenses on the basis of goods or services purchased. Salaries, wages, and fringe benefits for employees of transit agencies account for almost two-thirds of operating expenses.

Funds for transit operations come from a variety of sources: passenger fares, other transit agency earnings, and financial assistance from local, state, and federal governments. For transit agencies operating as a department of the local government, the greater portion of funds—more than half—comes from local and state revenues. Passenger fares and other agency earnings account for another 38 percent. Only 9 percent of operating costs are paid for by federal funds. Federal dollars fund substantially more capital investments, around 41 percent.

Transit funding from government agencies at all levels is the price governments pay for the benefits accrued to the community from transit services. The transit system reduces congestion and helps make possible the efficiency of high-density business development, both of which benefit all members of the community. Over 4 billion gallons of gasoline are saved by the combined reduction in private passenger vehicle miles, reduced automobile congestion, and reduced travel distances. The community also benefits from cleaner air that is the result of the 37 million metric tons of carbon dioxide emissions that transit systems prevent. The U.S. Environmental Protection Agency's Greenhouse Gas Emissions Calculator estimates that it would take 7.2 million acres of new pine or fir forests per year to match the annual carbon dioxide reductions provided by public transportation.

The 7,088 transit organizations, ranging from large multimodal systems to single-vehicle special demand-response service providers, also saved the American consumer dollars in 2010. The 4 billion gallons of gasoline saved annually through public transit, assuming gasoline is \$4 per gallon, saves \$16 billion in one year. Other savings include the reduction in costs of expensive personal vehicle parking structures, reductions in roadway injuries and fatalities, and savings in road construction and maintenance, police and emergency personnel service costs, and all of the costs that would result from increased sprawl if transit service were reduced.

Transit spending also provides jobs directly through transit system employees who operate and maintain the system's vehicles and facilities and those who administer the system and through employees of companies building transit stations, rights-of-way and other facilities or employees of companies manufacturing transit vehicles. Industries that supply goods and services such as materials and parts for building vehicles, guideways, and stations provide transit-related jobs indirectly. One analysis concluded that transit spending in 2010—\$17.8 billion for capital investment and \$37.8 for operations—supported nearly 2 million jobs.

Technology

Transit managers use transit management computer hardware and software to help them manage the day-to-day operations of the transit system, such as dispatching, service restoration, and service monitoring. A wide range of other technologies aid in managing a transportation network so that it delivers people and goods quickly, efficiently, and safely.

Communications links between transit vehicles and control centers provide information on fare payment, park-and-ride operations, high occupancy vehicle (HOV) and express bus lane access, intermodal communications, and emergency and security information. Geographic information systems (GIS) are computer-based systems that aid transit managers in service and facility planning for routes, assignments, scheduling, ridership, parking lot facilities, shelter locations, running times, accident analysis, and customer complaints.

With an electronic map and a relational database, GIS systems can guide operations using street and route maps, provide emergency call location identification, and make available vandalism

location and history. They can assist in market development by providing information on land uses, employment sites, demographics, and travel patterns. They can simplify customer information and service and analyze service performance statistics and adherence to the Americans with Disabilities Act and HOV violations.

Computer-based vehicle tracking systems, or automatic vehicle location systems (AVL), are one of the most valuable tools in transit management and operations. Used widely in military and emergency vehicle applications, AVL helps transit managers to increase operating efficiency, increase service reliability, improve response to service disruptions, improve detection of mechanical problems, improve driver and passenger safety and security, and various other tasks. Providing accurate information concerning the status and location of transit vehicles to travelers may also improve customer satisfaction and increase ridership. AVL can be a particular boon in providing location information to dispatchers in conducting demand-response routing and scheduling.

Many of these technologies also helped transit systems to respond efficiently to the U.S. Department of Transportation's 2009 initiative, the Mobility Services for All Americans (MSAA), which was designed to improve transportation services and simplify access to employment, health care, education, and other community activities by means of intelligent transportation systems (ITS) technology. The Intelligent Transport System–Joint Program Office under the Federal Highway Administration provided grant money to local communities to help them establish ITS-enabled transportation centers that featured simplified points of access, customer-based travel reservations, and information and trip-planning services. Some of the ITS technologies used included geographic information systems, integrated vehicle dispatching and scheduling, automatic vehicle location, communications systems, electronic payment systems/financial tracking and billing systems, and advanced traveler information systems.

The program helped provide access for older Americans, people with disabilities, and individuals with low incomes to work, school, social activities, and such essential trips as visits to the doctor.

Other technologies serve to make trips more pleasant and more secure for all travelers. Between

2001 and 2011, the number of buses equipped with automated stop announcements increased from 10 percent to 53 percent and buses with exterior bicycle racks increased from 32 percent to 74 percent. Perhaps more significantly, in the same period, the number of buses equipped with closed-circuit security cameras increased from 13 percent to 53 percent.

In the 21st century, transit systems have become more complex to manage and to operate, both technologically and financially. Social and economic changes, a global economy, and increasingly rapid changes in information technology suggest that the future will present greater complexity and more challenges for the transit industry.

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See Also: Federal Transit Administration; Intelligent Transportation Systems; Transit Finance.

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Transit Performance Monitoring and Evaluation

Performance measurement is used to some extent in nearly every organization as a tool to monitor how well it is functioning and how well it is meeting its goals and objectives. In the public transit industry, performance monitoring and evaluation can take many forms for different purposes, ranging from internal agency analysis to comprehensive trend analyses or peer review analyses conducted to fulfill requirements of the agency's governing board, local metropolitan planning organization (MPO), or state department of transportation (DOT).

No matter the type of performance evaluation, it is extremely important that the measures used be carefully selected and defined so that the exercise produces meaningful results. Data to compute the selected performance measures can come from a variety of sources, including manual compilation as well as electronic means using the latest technologies. One commonly used standardized data source is the Federal Transit Administration's (FTA's) National Transit Database (NTD). Regardless of the type of performance monitoring or evaluation used, appropriate interpretation and use of the results are critical.

Types

While some performance monitoring exercises may be required by an agency's governing board or other entity, it is still important for agencies to track performance internally. Further, agencies that are recipients of certain FTA grants (Urbanized Area Formula Program §5307 and Other than Urbanized Area Formula Program §5311, specifically) are required by statute to report data to the NTD. From the NTD data collection and reporting process, agencies have a wealth of information that can be used for performance monitoring and evaluation.

Results of performance measurement must be compared with something to be useful. Trend analyses are one way to compare an agency's current performance with its past performance. By examining trends in various measures over time, transit agencies can identify areas in which their performance is improving or not improving. Performance measures

can also be compared against some previously determined target level.

Another way to use performance measures is to compare them among similar agencies as part of a peer review analysis. Such an analysis allows an agency to have an understanding of how its own performance compares against a group of other agencies with similar operating characteristics and environments.

The selection of appropriate peers is a critical element for a meaningful analysis. A Transit Cooperative Research Program (TCRP) report, *A Methodology for Performance Measurement and Peer Comparison in the Public Transportation Industry*, is one source that provides guidance and a method for the selection of peer agencies, as well as a methodology for comparing the peers. In addition to ensuring that suitable peers are selected, the performance measures used in a peer review analysis must be chosen carefully.

For the effort to produce useful results, the measures used must be consistently defined among all the agencies included in the analysis. Data from the NTD are often used in peer review analyses because of the standardized reporting definitions for all agencies; however, other data sources may be used to incorporate other types of measures and information that may not be available in the NTD.

Performance Measures

As already mentioned, the selection of appropriate performance measures is essential for any type of performance evaluation. There are many statistics and measures that can come directly from the NTD or can be computed from NTD data. However, performance measures can originate from other sources, as well, including other databases, the transit agency's own route and schedule information, and demographic or geographic data from the U.S. Census, for example.

Data can be collected manually, such as during a ride check, which is when an individual rides a transit vehicle to count passengers, measure distances, and note travel times. Increasingly, certain types of data are collected electronically using technology such as automatic vehicle location (AVL) systems and automatic passenger counters (APCs). Travel times and distances can be measured using AVL systems, which track the location of transit vehicles using Global Positioning Systems (GPS) technology.

There are several different APC technologies that are used to count passengers as they get on and off transit vehicles along a route, as well as collect other types of data.

From all available data and information, performance measures can be produced. Most measures tend to be developed from the perspective of the transit agency. For example, common performance measures include ridership levels (number of transit passenger trips), number of trips per mile or per hour of transit service, and average transit vehicle speeds.

Common financial measures include cost ratios such as operating cost per passenger trip, per mile of transit service, or per hour of transit service. Another cost ratio, commonly known as the farebox recovery ratio, measures how much of an agency's operating costs are covered by revenues from transit fares. Transit agencies may also be interested in measures of performance related to vehicle maintenance and the frequency of vehicle breakdowns.

Transit agencies are typically interested in other types of performance measures that are also important to the transit passenger, or customer. One measure that has been shown to be of great importance to the transit passenger is the on-time performance of the transit agency's services. Most agencies continually monitor on-time performance, although various agencies may define "on-time" using slightly different thresholds.

Passengers also tend to be concerned about their safety, both while at a transit stop or station and while on the transit vehicle. As such, agencies must pay attention to safety-related measures, both internally and when required to report such measures to external sources such as their state departments of transportation or the NTD.

Transit passengers are also interested in how easy and quick it will be for them to use the agency's services for given trips. Performance measures related to how well an agency's service can meet the trip-making needs of the passengers include the frequency of service (how often the transit vehicles run), the span of service (how many hours in a day the service is available), how easy it is to access the transit stops or stations (are they located where passengers can access them, are the nearby pedestrian facilities adequate, is there parking nearby?), and geographic coverage (do the routes connect passengers' or potential passengers' desired origins and destinations?). *TCRP Report 100, the 2nd*

Edition of the Transit Capacity and Quality of Service Manual, provides a framework for analyzing transit service from the perspective of the transit passenger.

It is important to note that while some performance measures can be applied only at a system-wide level (for example, geographic coverage of the service), most measures can also be applied at the corridor, route, or route-segment level, depending on the type of analysis desired. Analyzing performance by transit route can be an instructive exercise when evaluating an entire system, and it can also be used in determining where service might be reduced when budgetary pressures force agencies to consider providing less service as a way to cut costs.

Challenges

For transit performance monitoring and evaluation, at any level, to provide meaningful results, it is critical that performance measures be selected with great care and with the goal of the effort in mind. It is also necessary that the measures be appropriately defined and that the proper data be available for the measures.

Sometimes, concerns may be raised regarding limitations with large databases such as the NTD. All data have limitations, but the NTD does have standardized definitions and definite reporting requirements. It can be expected that most agencies are reporting those data in the same way, thus making the NTD very useful for performance evaluations including peer review analyses.

Regarding peer review analyses, the selection of appropriate peers has already been emphasized. However, for a peer review being conducted at the request of a governing board or other external entity, an agency may feel pressured to present favorable results and may select peers it knows it can outperform, even if they are not necessarily the best peers. Or, an agency may be told to include a particular transit system as a peer that may be located in a nearby city, or in a city that is often compared to the agency's own city in other ways, even if that particular transit agency were actually a poor peer based on other key characteristics.

Issues such as these further highlight the need to select only appropriate peers. Using a set methodology to select peer agencies can assure governing boards and others of the validity of the peer-review analysis. Further, following a methodology that can

be readily explained to others, for any performance monitoring or evaluation effort, will increase the credibility of the results when shared with others.

When results of performance evaluations or peer review analyses are shared externally, some within a transit agency may express concern about how the information might be used. Similarly, when external groups or organizations use publicly available data to conduct their own performance evaluations, or to compare and rank transit agencies, it can be challenging for an agency to respond, particularly if it seems that the external group did not use appropriate information, or left out pieces of information critical to the agency's performance.

These issues, among others, underscore the importance of recognizing the proper role of transit performance monitoring and evaluation. It must always be remembered that there may be many factors that affect a transit agency's performance that are outside the control of the agency itself. While some performance monitoring systems may be quite comprehensive, many exercises in performance evaluation and, particularly, peer review analysis should be regarded as only one tool out of many to be used in gaining an overall better understanding of a transit agency's performance.

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See Also: Automated Passenger Counters; Automated Vehicle Location Systems; GPS; Transit Industry, Economics of; Transit Management and Operations; Transit Systems, Service Quality of; Transit Systems Analysis.

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Transit Planning, International

Because land uses generate and attract trips, and the transport system creates nodes of high accessibility (central places) where land uses are concentrated at higher densities, it is logical to plan transport and land use together. This, however, is easier said than done, because land tends to be in private ownership and the transport system in public hands. There is a disconnect, then, between the ownership of transit and most land uses.

If city planners concentrate only on transport or transit planning, there is a real problem of synchronicity. This is particularly true if assumptions are made about what landuse development might take place to justify or support a transit project, and the private landowners fail to deliver the development because, for example, of a downturn in the property market. On the other hand, land development may become a self-reinforcing cycle, creating greater movement demands than the transit project can accommodate.

Transport Objectives

All planning must begin with clear objectives. These are either abstract (for example, improving transit services) or concrete (for example, increasing ridership by 20 percent). From the objectives, a set of policies is prepared to achieve the objectives, and then an action plan is developed to put the policies into practice.

The action plan can be physical (for example, building a new transit line) or administrative (for example, reducing fares or increasing parking charges). Finally, the results of the plan must be monitored to ensure that the objectives are indeed being achieved, without any unintended consequences.

If there is a departure from the desired objectives, then this cycle should be repeated from the

beginning. The problems of restarting the planning process are likely to include the time frames and, less likely, a change in the continuity either of local political control or of the professional staff who were responsible for the first-round plans.

Process

There is an important step that may be required at each stage of the process, namely, public consultation, which can also be used to provide market research information. For public consultation to have merit, it must be undertaken with good will, which means that the transit planners are prepared to modify or even abandon plans as a result of public feedback. If the project is going to be pushed through regardless of public opinion, there has not been consultation, only information on a take-it-or-leave-it basis.

Public Consultation and Involvement

Most countries that are members of the Organization for Economic Co-Operation and Development (OECD) undertake public consultation as a formal part of the planning process. For this process to be productive, the public must be given the information to explain why a plan is required and what the plan is. This information must be intelligible in nontechnical language. Such consultation may benefit from a pilot exercise to ensure that the information is relevant and understandable, and members of the public can make meaningful responses.

This public consultation will use all practical media to make people aware of the process and where and how information can be obtained, if it is not distributed to all households and businesses affected. With the advent of the Internet, and most people having access to it at work and/or at home, most information can be distributed via a dedicated transit plan Web site.

The site can also include a feedback questionnaire, not just on people's views about the project, but also their present travel patterns. As well as recording present travel behavior, this also allows an assessment to be made of people's attitudes toward a new transit service. Attitudes, however, are a notoriously unreliable indicator of future behavior changes.

Demand

Over the last 50 years, the number of trips people make has remained remarkably constant. What has

changed is the average length of those trips and their origins and destinations. Origins have changed as people have moved homes and workplaces.

These changes have taken place because the real cost of travel has fallen. As economists know, demand and price are inter-related; lower prices equal higher demand. Since travel costs have fallen, and people can only make one work trip per day, lower costs have translated into longer journeys. There has also been a major social shift since 50 years ago, when many people lived close to their workplace and went home for lunch.

Therefore, in planning for transit, the number of trips people make is nearly fixed. What is available for change are travel mode, destinations, and times. In the longer term, planners could see changes of origin as some people move to be close to a convenient rapid-transit facility.

Buses, which in many cities provide the largest network of transit services, are often not carrying many passengers. In most cities, bus passengers are considered "captive and with low incomes." They are captive because they have no car or are unable to drive a car. Lower income is a factor because higher-income people without a personal car have other options, such as taxis. Planning for bus services is therefore about serving the maximum number of low-income households, with links to the most frequently used services (for example, business districts, shops, medical facilities, schools, etc.). Such planning will often revolve around cost minimization and service maximization.

In 1992 in Los Angeles, California, the so-called Watts Riots were fundamentally caused by a high level of unemployment in a city with many job vacancies. One of the outcomes of that disturbance was the provision of bus services from Watts to major employment areas. This resulted in a reduction of unemployment. After two years, many of the bus services were withdrawn for lack of demand, because newly employed workers were able to afford cars to travel to work.

Historically, calculating the demand for transit improvements begins by constructing origin-destination (OD) matrices for work journeys, school, leisure, and so forth. Future transit demand is then estimated using diversion curves of the relative attraction of transit compared to a personal car. For the purist, such an analysis is first conducted for present travel to allow the diversion curve model

to be calibrated against the present modal split between cars and transit.

This approach has a number of weaknesses. First, it assumes that present behavior will be unchanged in the future. Second, it assumes that people will hold the same attitude toward a new transit service as they do for the present service. That logic would result in only modest transfers of trips from cars to transit. Forecasts of future transit use have been unreliable in the past, either overly optimistic, with the planned facilities underused, or overly pessimistic, with ridership exceeding forecasts and causing short-term overcrowding, which could prompt some passengers to leave the system. In the medium term, the problem of crowding can be accommodated by careful service management or additional investment in new rolling stock or more stations.

Getting the forecast right is clearly important whenever planners are looking to justify a new investment in transit. Investing additional time at this stage—to undertake further local research on the likely behavior changes or explore similar programs in other cities to get more confidence in the probable demand—planners can make a big difference in the outcome of the project without adding much cost or time.

Competition Between Modes

In most cities, there is little or no competition between modes of travel. The car is “King.” For those people with a car, it is usually the automatic choice.

For transit to create a semblance of competition with the car requires a very special effort and approach. The first stage, as in demand forecasting, is to find out where most car trips originate and are destined. This allows an assessment of those travel flows to be made and the identification of those large enough to be considered economical for a transit service.

The next stage is to find out from present car users the conditions required to attract trips to transit. This should be not only in terms of travel cost comparisons but also in terms of the convenience of accessing the proposed transit service. Few car users will be within walking distance of a new transit stop and some may be within cycling distance, but they will want to use safe cycle paths.

For most, the only practical access to a transit station is by car at a park-and-ride parking lot. The

location of these lots is critical, both to ensure the shortest possible travel time for commuters from door to door, which will be the main comparison used by commuters, but also to cover the costs of providing the service.

Park-and-ride stations need to be near the home end of the journey. Commuters will not usually drive three-quarters of the way and complete the final quarter of the journey by transit, unless congestion or parking are particularly difficult at the destination. Planning for park-and-ride is not always easy, because few people want one next to their backyard.

However, industrial locations present an unattractive place for people to park their cars, unless there are very special measures in place to secure the safety of cars left parked for most of the day and to make people feel safe walking to and from their cars, especially in darkness.

A park-and-ride station typically will be a large parking lot with a small transit station footprint. This provides an opportunity for public art and landscaping to soften what would otherwise be a hard cityscape. Even grass can flourish in many areas of a parking lot, softening the look of the site and making a modest contribution to carbon capture.

Who Is Responsible?

City planning is the responsibility of the city council. Some transit authorities are set up as either autonomous or semi-autonomous from city hall, which can create conflicts of interest and policy. What the transit operator thinks might be good for transit, city hall may view as bad for the city.

So, how can policy and planning be coordinated? It usually comes down not to processes or procedures but to the trust that planners have for the other side. This is intertwined with the ability of both parties to share common goals and then work toward joint objectives. Indeed, each may be able to bring different things to the party, and the sum of the whole can be greater than the parts.

The transit operator will have the responsibility to provide the transit service, the land uses of which may need city hall approval. City hall can bring traffic management, parking controls, and general land use policies that will support transit improvements and encourage transit use. Setting an example is always important in public policy. The mayor and staff using transit themselves is a way to give transit

a big vote of confidence. Citizens will therefore have fewer reasons not to consider transit.

An example of how this can be influential comes from Groningen in the Netherlands, a town of 190,000 people, which by 2000 had seen a major shift in modal split. Car use was 60 percent, bus use 10 percent, and biking and walking made up 30 percent. This was causing major congestion and pollution problems. The city council decided that for health and environmental reasons, car use should be reduced to 30 percent, while bike use would increase to 40 percent and bus ridership to 20 percent.

The first stage in implementing this policy was abolishing free parking for council staff and councilors and putting in more bike parking at city hall. This example and other measures to encourage bike and bus were successful. By 2002, bike use was 55 percent of trips, bus transport rose to 15 percent, and car use dropped to 20 percent of trips. The public opinion of this change has been highly supportive. The benefits include less traffic, congestion, noise, and pollution, along with faster journeys, even on bikes. With more people commuting to work by bike, the health of the population has also improved.

Changing attitudes and behavior can improve the image of transit as well as encourage a modal switch away from car trips. This does not require a financial investment, but it is not necessarily easy, either. The starting point is that those planning the transit improvements believe in them enough to use them for their own travel.

Time Frames

The time frames for transit planning can be as short as six months or as long as 10 years. It took the car industry nearly 50 years to achieve travel dominance, even if auto manufacturers were not always playing fairly. Determining the required time to achieve a planning objective is an objective itself and will depend on the size and scope of the project being planned. The time taken to introduce a dedicated bus lane on a freeway, for example, will be less than what is needed to build a busway or light rail line. The time required to build a subway is much longer still.

The timeline for each planning objective will include public consultation, feedback, plan adjustment, further consultation, and then getting approval. In comparison, the time required for the engineering designs and final construction might be quite short.

Funding and Implementation

Because most transit plans are publicly funded, getting a budget approved can be the most time-consuming part of the planning process. In the political calculus, a dollar spent on transit must be weighed against the value of spending that dollar on schools, libraries, parks, and so forth. Cost is a particularly sensitive issue for transit projects, which tend to cost in the hundreds of millions of dollars, one of the largest single expenditures most local governments will ever plan.

Raising the funds becomes even more difficult when part of the money must come from a central or federal government, which will have additional conditions and regulations and will take much longer to approve. At the federal level, the calculus requires trading off expenditures in City A against City B and so forth.

If a project can be locally funded, it can be done more quickly and with fewer conditions. There are several ways in which this may be possible. In the United States, borrowing money (for example, in a bond issue) will need to be underwritten by additional tax revenue (for example, a sales tax hike). This in turn may require a referendum, which can also be used to provide feedback as part of the public consultation process.

The United Kingdom pioneered the Private Finance Initiative (PFI), where the authority makes a deal with a consortium of companies, including a builder, to construct the required transit facility. The private consortium, then, raises the cash needed on the basis of its financial standing. The transit operator agrees in return to make payments over, typically, a 20-year period, at which time the consortium has been fully repaid its costs and profits, and the operator owns the facility.

There is an interesting twist to PFI, which lawyers and financiers devised. When the consortium initially raises the funds to build the high-risk transit project, the cost of borrowing will also be high, typically 15 percent above the bank rate. The project may take two years or more to build. At that point, there is a concrete asset. The consortium then refinances the project, paying off the high-cost money and replacing it at more usual terms (for example, 4 percent above bank rate). Meanwhile, the transit authority continues to repay the consortium at the terms originally agreed. By this means, the consortium can over 20 years make a 100 percent profit.

Usually, though, the transit operator will either use its own funds or raise a bond issue, and then get contractors and equipment suppliers to bid competitively to build and equip the facility. This process can also have its drawbacks, especially if the transit body lacks the expertise to evaluate the bids, both technically and in financial terms, or to supervise the construction, the cost of which can escalate quickly and dramatically.

Modal Choice and Hierarchy of Modes

For a metropolitan area to have the best transit network will involve a number of different modes operating in a synchronized hierarchy. The planning of such a hierarchy is in some sense like designing a building. The foundations must be right before the walls and roof can be added.

Nevertheless, the benefits of seamless journeys from people's homes to their destinations on one or more modes of transit are both satisfying for the commuter and economically efficient for the community the transit system serves. Offering a fast and frequent transit service, even if it requires changing mode en route, is the most effective way to get car users to switch some of their trips to transit.

Interchanges and Nodal Stations

Planning interchanges and nodal stations can be the most challenging part of the transit planning process, even though all stations are effectively interchanges (for example, between walking and transit). Only those providing interchange between two or more transit lines or modes are discussed. Nodal stations are primary stations because they are serving the Central Business District (CBD), airport or other major traffic generator or attractor.

Finding and securing the land for such stations can be very challenging, even if the transit operator uses compulsory purchase powers, because these facilities can have major impacts on both the community and the political support needed to achieve the project. Getting the land together by private purchase is the most civilized method, unless it leads to "planning blight," which effectively destroys the value of surrounding property and begins a downward spiral of property neglect and dereliction.

The transit authority will wish to be a good neighbor in acquiring property. This will include designing an infrastructure that enhances the local

neighborhood. Indeed, this may be the opportunity to raise civic pride by having a competition of architects to design the new facility and inviting local people to select the one most liked.

Beware, however, that most people cannot read an architect's plans, so the choice will need to be based on a model, which can be physical or a three-dimensional computer-generated graphic. This can show the station's convenience, novelty, and beauty, as well as how it will operate, and help plant seeds for attracting car commuters when it finally opens.

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See Also: Metropolitan Planning Organizations; Regional Transportation Planning; Regional Transportation Planning Organizations; Regional Transportation Plans; Transit Lines/Networks; Transportation Planning.

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Transit Priority Measures

Transit priority measures are devices employed to improve the travel-time reliability and speed competitiveness of transit services relative to general traffic. Investment in transit priority measures can serve other purposes, including the following:

- Supporting strategic policies, such as urban consolidation, network efficiency,

and environmental management (for example, carbon reduction)

- Improving safety through remediation of conflict points between transit and other modes, particularly pedestrian and cyclist access to transit stops
- Improving passenger comfort through a more direct, less stop-start service
- Delivering better network coverage and integration
- Generating operating and capital cost efficiencies

Plainly, these reasons are not mutually exclusive, and they may singularly or in combination drive an investment decision by transit planning authorities.

Types of Transit Priority Treatment

There are a range of treatments, and these may be grouped according to whether they represent a location-specific point treatment (often at intersections), corridor treatment, or technological investment. The measures are most often applied in locations within an urban road network where there is congestion, with the degree of prioritization dependent on the frequency of bus services and how significant and extensive the congestion is.

By prioritizing transit, authorities may not only reduce service delays and operating costs but leverage more patronage as frustrated drivers identify a relative benefit in using buses. Some priority measures also may only apply at certain times of the day, most commonly during commuter peak travel hours.

Generally, the case for transit prioritization in urban areas across the world is gaining popularity. This reflects the deepening understanding that policy makers have regarding the impacts on productivity associated with traffic congestion and delays. Moreover, there is increasing evidence that congestion cannot be alleviated over the medium and long term through additions to road capacity.

Increasing urban populations and increasing or relatively stable car ownership rates contribute to congestion issues. The need to address the effects of congestion is becoming more evident in developing as well as developed countries, while issues of chronic underinvestment in transit infrastructure in some contexts and its implications become clear. The legacy can include lost productivity, car dependence, and poor air quality.

Overview of Point or Localized Treatments

Typical point treatments include bus queue jump facilities and transit gates or “plugs.” Queue jumps are intended to permit buses to circumvent queues, or lines of traffic, that form at congestion points (typically traffic signal–controlled intersections).

They may also be implemented in partnership with midblock signals to meter traffic and ramp meters at entries to freeways and highways. Queue jumps are effective only if they are of sufficient length to permit a congestion point to be bypassed; if general traffic queues frequently extend back past the entry to the bypass lane, they become ineffective.

On approach to intersections, physical barriers do not usually separate queue jump lanes from adjacent traffic lanes. This is because it is often desirable or a legal requirement to permit turning traffic to enter the queue jump lane, but only a short distance from where a cross street or crossover is located. At intersections, queue jump facilities can be established as either curbside or median lanes, depending on the direction in which transit services need to travel.

Physical barriers can be more appropriate on ramps and midblock, where intrusions by general traffic may need to be avoided. Transit gates are used to help control access to these kinds of midblock facilities and may also control access to corridor treatments. Using intelligent transport systems (ITS), such as Global Positioning System (GPS) transponders on buses, gates may be raised only when a bus fitted with the technology onboard actuates the activity. At other times, traffic is precluded from entry.

In Europe, “sump busters” (a solid mass designed to destroy the oil pan of any vehicle with an insufficient ground clearance to avoid the obstacle) are sometimes incorporated as point treatments at entries to bus-only facilities, because buses have sufficient axle width to pass over them.

Transit plugs are short links that permit buses, but not general traffic, to cross a reserve or other land area and thus avoid a circuitous detour. Transit plugs often demonstrate a compromise between bus operating requirements and a desire to preserve the integrity of the land use that the infrastructure crosses; that is why the exclusion of general traffic is desirable.

Transit malls are similar to transit plugs insofar as they serve as a transit-only link between two road corridors. However, they have a critical land

use component that transit plugs do not. Transit malls are generally lined by building development with retail premises on the ground floor. The transit service helps activate the land use by supporting pedestrian activity, and transit stops within the mall are an important element of the treatment. The Bourke Street Mall in Melbourne, Australia, provides a good light rail–based example.

Overview of Corridor Treatments

Corridor treatments include transit-priority lanes. These can be fully exclusive, partially exclusive, or nonexclusive. Fully exclusive lanes represent the most aggressive road-based transit solution and generally require the highest level of investment. They are, therefore, adopted as the preferred treatment for trunk routes where there is significant patronage. These lanes need to be physically separated from general traffic, and entry to the lanes should be managed through use of actuated barriers or similar. While they can deliver the greatest amount of transit service reliability and support high operating speeds because of the reduced risk of conflict with other modes, they can be physically divisive phenomena within the urban fabric.

The TransMilenio system in Bogotá, Colombia, is one of the most famous exclusive bus rapid transit (BRT) systems in the world. The busiest corridor within the system (Caracas) carries upward of 45,000 passengers per day, and the operating profile of the system requires facilities at some stops to permit overtaking (passing). TransMilenio has significant at-grade operations, which affects cross-corridor movements by other modes of transport.

In Brisbane, Australia, the BRT system has a significant grade-separated component to alleviate some of the movement restrictions for other modes. However, this has come at considerable capital cost.

Partially exclusive and nonexclusive transit lanes may be provided either curbside or in the median of road corridors. Partially exclusive lanes may have intermittent physical barriers—crossing movements may only be permitted at intersections—whereas nonexclusive lanes may only be differentiated from standard pavement by a particular color treatment (for example, red or green).

Nonexclusive lanes tend to be intruded by general traffic most frequently, with consequential impacts on the reliability and operating speed of transit services. They are a comparatively cheap



An example of a bus queue jump lane on approach to a signalized intersection along Great Eastern Highway in Perth in western Australia. At intersections, queue jump facilities can be established as either curbside or median lanes.

corridor treatment and best suit corridors where there is a need to retain opportunities for frequent cross movements. Given a lack of physical separation between bus and general traffic lanes, monitoring and enforcement can become important. This may be undertaken practically through use of closed-circuit television (CCTV). Through application of dynamic signage/ ITS, partially and nonexclusive lanes can operate with contra flow or only during peak periods.

Overview of ITS Treatments

There are a range of ITS solutions associated with traffic signal control along transit routes. These measures represent the third of the three main groups of priority measures, along with the point and corridor treatments. Passive signal priority systems do not have to be actuated by transit vehicles. They occur automatically during designated periods. Passive systems may therefore be



This transit plug allows traffic to pass through public open space in the suburb of Kardinya in Perth, Australia. Transit plugs may be enforced through closed-circuit television monitoring.

criticized for generating inefficiencies, because they can reduce the level of service for general traffic whether or not transit vehicles are benefiting.

Passive systems include the following:

- Transit-signal timing, which has to be coordinated carefully with transit timetables and may not work effectively if services experience delays upstream and do not arrive at intersections when expected
- Priority movement repetition (for example, multiple phases favoring transit within one signal cycle), which reduces incidences of delays for transit vehicles
- Green priority weighting (for example, longer green-light phase time for transit vehicle movements)
- Reduced cycle time, which is useful for transit if services approach on minor

legs at intersections, because the applicable green signal phase will occur more frequently

In contrast to passive systems, actuated systems have to be “called up” by approaching transit vehicles through application of onboard GPS transponders or travel across detector loops. The relative benefit of actuated systems is that they are demand responsive and can therefore reduce inefficiencies within the broader traffic system. The second and third benefits are the reliability that the transit service will arrive at an intersection at the right time to benefit from the priority treatment and the opportunity to compensate for increased green time for transit between actuated phases, respectively.

Actuated systems include the following:

- Green light pre-emption (for example, green phase call up)
- Green phase extension
- Multisignal linking along a corridor (although this can be complicated by the location of intermediary stops), creating a green wave

ITS solutions can be set up to apply only during peak hours. This may be suitable on networks that exhibit “high tide” congestion (that is, pronounced peaks and long inter-peak troughs). Typically, peaks occur in the mid-morning and late afternoon as a function of commuter travel. In many cases, peak traffic flows are in one direction—hence, the idea of tidal flow—based on the agglomeration of jobs in one location (for example, a central business district) and residences elsewhere.

Some physical point and corridor treatments can also be effective as peak hour transit priority devices, such as the curbside bus priority lanes.

During the intra-peak, signage and thermoplastic stenciling on the road surface inform general traffic that the lanes are for buses only. Outside of these times, general traffic can use the lanes and, in some instances, curbside parking is permitted. In some cities, similar lanes are provided in the median with the direction of flow for transit reversing depending on the peak direction of traffic. Time-based exclusivity becomes infeasible when physical separation is incorporated in priority treatments.

Selection of Priority Treatment

Policy makers and planners will generally go through a set of criteria to select the appropriate transit priority measure for a given geography. Plainly, the selection process will be influenced by the extent of congestion on the existing road network, service travel times, expected growth in travel demand, and budget implications. However, other pertinent considerations include the following:

- Number of services affected per hour in each direction
- Patronage for each service and overall during the period of interest
- Constructability of physical measures, which is affected by existing road geometries, frequencies of road crossings and crossovers, reserve widths, and servicing infrastructure
- The potential efficacy of a treatment (that is, what are potential, quantifiable benefits?)
- Hardware and software requirements (where ITS is involved)
- Social and political acceptance

Some transit authorities, such as the Public Transport Authority of Western Australia, have established guidance patronage thresholds for helping decide cases for investment in corridor-based exclusive bus infrastructure as compared to very localized or semi-exclusive priority facilities. These thresholds may also be considered based on overall corridor capacity. For example, bus lanes along very busy routes can carry more people than a general traffic lane. Within such a context, if latent demand for prioritized transit services is high, reallocation of traffic lanes can be warranted.

While it is generally accepted that investment decisions should be made on a case by case basis, there is still an expectation that there is strong justification for whatever treatment is specified. Often, multi-criteria analysis comparing various treatments with a business-as-usual scenario is necessary. Typically, this will incorporate traffic analysis that considers both impacts on transit and general traffic. The latter can be impacted by variables including the following:

- Transference of road space from general vehicles to buses

- Allocation of green time at traffic signals to bus-only phases or phases that support bus movements
- Reduced network connectivity and lot access created by physical barriers to entry to bus lanes

Otherwise, transit service philosophies can exert a strong influence. These can range from treating transit as a basic social good, and therefore only minimal investments are supported, through to a city forming tool and strong alternative to private vehicle travel. In the latter case, transit priority measures may be implemented aggressively to provide transit services with a strong competitive advantage over general traffic, even on secondary (that is, nontrunk) routes.

Increasingly, authorities also need to be aware of the costs of not investing in sufficient transit priority, which can include added costs—economic, environmental, and economic—associated with congestion and unintended impacts on urban form.

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See Also: Bikeways/Bike Lanes, Road Design Issues of; Bus Rapid Transit; Busways and Reversible Bus Lanes; Traffic Signal Priority; Traffic Signals; Transitways.

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Transit Ridership

During the 19th century, changes in public transport technology shaped transit affordability and ridership in the United States. In the 1820s and 1830s, only wealthy individuals could afford to ride the first type of public transport in U.S. cities—horse-drawn rectangular boxes on wheels called omnibuses. Steam railroads, initially introduced in the 1830s, were able to lower operating costs over time and by the middle of the 19th century became affordable for the middle class for commutes from the suburbs to the city center.

The horse-drawn railcar—essentially a horse-drawn omnibus on rails—and later the electric streetcar made urban transit within cities affordable for all but the poorest. Replacement of streetcars with motorbuses began in the early 1900s. Overall, public transport in the United States experienced a steady growth in passengers until the 1920s, when ridership declined during the Great Depression that saw high unemployment and bankruptcy of transit systems.

After initial declines in patronage during the 1920s and 1930s, public transport ridership surged during World War II. Public transport reached its peak ridership with about 16 million passengers per year during that time. The rise in transit use during the war was fostered by wartime fuel and tire rationing and the use of automobile factories to construct military vehicles instead of automobiles.

The decline of transit demand that had started in the 1920s and 1930s was only interrupted during World War II, however. After the end of the war, in the face of rapid suburbanization and skyrocketing automobile ownership, demand for public transport in the United States fell sharply, from 16 billion passengers per year in 1945 to 5 billion passengers per year in 1973. Moreover, in many parts of the country, public transport, and especially buses, became the mode of transport of last resort. Ridership was often limited to those who could not afford an automobile.

Since the 1970s, public transport demand has increased steadily and reached 7 billion passengers per year in 2010. Fluctuations in public transport ridership between 1973 and 2010 were related to economic cycles and gasoline prices, with higher levels of ridership during economic booms and periods with higher prices for gasoline.

In 2010, Americans made about 25 trips by public transport per year. This compares with much higher levels of transit ridership in Switzerland (237 trips per year), Germany (139), Sweden (139), the United Kingdom (116), Belgium (100), Norway (96), France (87), Spain (78), Finland (73), Italy (65), and the Netherlands (51). Even Canadians, America's neighbors to the north, made twice as many transit trips per year (51).

In spite of increasing total ridership annually, public transport in the United States has not increased in terms of share of trips, because of a still growing number of trips by automobile. As a result, since the 1970s, public transport in the United States has accounted for roughly 2 percent of all trips.

By contrast, public transport's market share in Europe is much higher, reaching 10 percent in countries such as Germany, Sweden, Great Britain, and Norway, and 5 percent to 10 percent in the Netherlands, Finland, Denmark, and France. In Switzerland, over 20 percent of all trips are by public transport. In Canada and Australia, public transport accounts for 1.5 to two times higher shares of regular commuters than in the United States. Trends are also more favorable in European countries and Canada, where public transport has increased its share of all trips over the last two decades.

In all countries, the demand for public transport varies by demographic and socioeconomic characteristics, trip purpose, mode of public transport, and land use. In this article, these trends are highlighted for the United States, with occasional references to European countries, such as Germany, to highlight unique aspects of public transport in the United States.

Rail Versus Bus and Trip Purpose

In the United States, the majority of public transport trips (roughly 70 percent) are by bus. Rail only accounts for 30 percent of public transport trips. In European countries, public transport demand is more equally split between bus and rail modes—often with a slightly higher share of trips by rail than by bus. For example, in Germany, 57 percent of transit trips were by rail in 2009 (compared to 43 percent by bus).

Public transport demand in the United States is dominated by commute trips to work, which account for about 40 percent of all transit trips, followed by personal business (32 percent), social/

recreational (20 percent), and educational (12 percent) trip purposes. In western Europe, the commute is less important for public transport demand, because public transport is a viable option for many trip purposes and at all times of day.

In some countries, trips for educational purposes account for a high share of transit trips. For example, in Germany, commute trips to work accounted for 24 percent of transit trips and trips to and from school made up 25 percent of transit trips. In European countries, such as Germany, school children often ride public transport to and from school.

In the United States, school systems typically have their own fleets of school buses. In 2010, there were five times as many school buses as public transport buses in the United States. However, school buses are not considered public transport, because school buses are used only by school children and are not open to the public.

Rider Demographics

Women ride public transport at a higher rate than men in the United States: 2 percent of trips by women versus 1.8 percent of trips by men. The 16-to-24-year-old age group has the highest share of trips by public transport (3.1 percent), followed by 25 to 44 year olds (2.1 percent). Public transport ridership is lowest for those between age 5 and 15 (1.1 percent of trips) and those older than 65 years (1.4 percent of trips). In western European countries, such as Germany, women also ride transit more than men (8.8 percent versus 8.2 percent of trips).

However, transit ridership does not fall with age in Europe. For example, in Germany, public transport accounts for 8 percent of trips by those 65 and older, compared to only 5.5 percent for those between 45 and 64. Overall, public transport ridership is higher for all groups in Europe.

In the United States, racial and ethnic minorities—particularly African Americans—use public transport at a higher rate. In 2009, African Americans accounted for only 12 percent of the U.S. population but 32 percent of all transit riders. By contrast, whites accounted for 73 percent of the population but only 39 percent of transit riders.

Socioeconomics

Public transport ridership falls with increasing automobile ownership and incomes. In fact, in 2009, public transport in the United States accounted for

21.6 percent of trips for individuals who did not own a car, but less than 1 percent of trips in households that had more cars than licensed drivers. The group of individuals that do not own a car can be divided into at least two subgroups: those who do not wish to own a car and those who cannot afford to own an automobile but would like to own one. Both groups depend on public transport for a high share of trips.

Individuals in the lowest income quartile made 4.1 percent of their trips by public transport compared to only 1.1 percent of trips by public transport for individuals in the highest income quartile. Incomes of public transport riders also differ by mode of public transport. In 2009, bus passengers had a median household income that was only one-third of the median household income of rail passengers (\$22,500 versus \$ 65,000).

In fact, median household income of rail passengers was higher than the national average (\$50,000). Part of this is explained by the concentration of commuter rail systems and subways extending to high-income suburbs surrounding San Francisco, California; Washington, D.C.; Chicago, Illinois; and New York City. Buses, by contrast, serve poorer inner-city neighborhoods and are often stigmatized as a transport option of last resort.

In European countries, such as Germany, incomes of bus and rail passengers are comparable to national median incomes. Moreover, public transport attracts a higher share of trips from high-income individuals and those in households with more cars than drivers, which make 8.4 percent and 5.7 percent of their trips by public transport, respectively.

Land Use and Spatial Distribution

In the United States, public transport ridership is concentrated in large metropolitan areas. In 2010, the New York City metropolitan area accounted for 40 percent of all transit trips in the United States. Combined, the Boston, Chicago, Los Angeles, New York, Philadelphia, San Francisco, and Washington, D.C., metropolitan areas accounted for roughly 70 percent of all trips by public transport in the United States.

Moreover, public transport ridership is highest in higher-density areas. In 2009, public transport accounted for 11 percent of all trips in areas with a population density of more than 4,000 people per square kilometer (3.86 miles). Conversely, only 0.3 percent of trips were by public transport in areas

with population densities of less than 300 people per square kilometer.

Public transport use is also more common in larger metropolitan areas. Transit accounted for 2.9 percent of trips in urbanized areas larger than 500,000 inhabitants, compared to only 0.2 percent of trips in rural areas. Transit ridership also varies by region of the country. In 2010, the transit share of trips was 5.1 percent in the northeast census region, 2 percent in the west, 1.2 percent in the midwest, and 1 percent in the south.

In European countries, public transport ridership is more equally distributed across cities and other parts of the country. For example, even small towns, such as Freiburg, Germany, have ridership levels of 18 percent and higher. Similarly, the difference in the transit share of trips between German states ranged from a low of 6.3 percent in Lower Saxony to a high of 8.9 percent in the state of Hessen.

In 2009, public transport accounted for 5.9 percent of all trips in rural areas in Germany, and 17.7 percent of trips in urbanized areas with more than 500,000 inhabitants. German public transport also attracted 6.1 percent of trips in low-density areas (fewer than 300 people per square kilometer). In high-density areas (that is, 4,000 people per square kilometer), 16.2 percent of trips were made by public transport.

Policies to Increase Ridership

Higher levels of public transport ridership for all groups in Germany than in the United States can be explained by several factors. First, compared to the United States, Germany has more and higher-quality public transport services. Second, in Germany, most transit agencies offer steeply discounted monthly and annual tickets that attract regular riders.

Third, regionwide coordination of transit services and fares in Germany allows passengers to conveniently change between rail and bus transit and across operators with one ticket. Fourth, gasoline taxes, traffic calming, strict speed limits, parking restrictions, and fees for car parking make car use more expensive and slower in German cities.

Finally, land use policies in Germany discourage low-density and single-use suburban sprawl and foster dense and mixed-use developments that can be effectively served by public transport. In the United States, there are some successful examples, such as the Rosslyn-Ballston Corridor in Arlington,

Virginia, that demonstrate that mixed land uses and high population densities can help promote public transport in suburban areas.

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See Also: Transit Demographics; Transit Planning, International; Travel by Mode; Travel Patterns by Income.

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Transit Safety

Public transit, including buses, commuter trains, light rail, and subways, is a generally safe mode of transportation, particularly when compared to driving in private cars. Although public transit systems have the potential to act as crime magnets, bringing together large numbers of people into relatively confined areas, transit areas (for example, buses, trains, and stations) are as safe as, or safer than, the corresponding city streets.

Various approaches have been taken to reducing both transit crime and the perception of crime on

transit, including increasing police presence, maintaining a clean and orderly environment, enforcing regulations strictly, and prosecuting even minor crimes (a “zero-tolerance” approach).

Bus Accidents

In the United States and many other countries, bus travel is relatively safe, and serious accidents are rare. According to the Fatality Analysis Reporting System (FARS), which contains information about fatal traffic crashes in the United States and Puerto Rico, there were 43,945 fatal traffic accidents in the United States and Puerto Rico in 2011, of which 535 (1.2 percent) involved a bus; the preponderance of fatal accidents involved either passenger cars (39.7 percent) or light trucks (37.2 percent).

In the same year, there were more than 2.7 million accidents causing injury, of which 6,000, or 0.2 percent, involved a bus. Of the 6,612,000 accidents causing property damage in 2011, only 7,000 (0.1 percent) involved a bus. Of 27,060 vehicle occupants killed in traffic accidents in 2011, only 54 were bus passengers, and of the 2,091,000 vehicle passengers injured in traffic accidents in 2011, about 13,000 were bus passengers.

The Transit Cooperative Research Program of the U.S. Transportation Research Board identified a number of practices that are associated with accident prevention in bus operations. In the area of human resources, these practices include screening potential drivers through structured interviews and work sample tests, as well as a review of their driving records and prior employment histories. Also included were providing defensive-driving training, offering incentives for maintaining a clean driving record, and educating passengers, including school children, in safe riding practices.

Management activities associated with greater safety include tracking and analyzing accidents, educating the public, identifying hazards, performing safety inspections, and supervising drivers. Operations activities associated with increased safety include locating bus stops with traffic patterns in mind, removing snow and ice during inclement weather, enforcing traffic and parking laws, and using unidentified observers and surveillance video technology on buses.

A researcher investigating data from intra-city bus routes in Uppsala, Sweden, found that several factors were related to the occurrence of bus

accidents. As is true with driving accidents in general, traffic density was strongly related to accident occurrence, with the morning and evening rush hours being the most likely times for accidents to occur. The influence of heat and rain on bus accident rates was also investigated, but no evidence was found that either condition was significantly related to the occurrence of accidents, in contradiction to what some other researchers had found.

Bus Crime

Minor crimes, including theft and robbery, are typical crimes committed on buses, while violent crimes are less common. Crimes often reflect typical patterns of crime in a given city, as well as general societal factors. For instance, the increasing prevalence of electronic devices such as smartphones, which make promising targets for thieves, has been blamed for a 42 percent increase in thefts on Chicago Transit Authority (CTA) buses and trains from 2009 to 2011.

Opportunity is also a factor. For instance, New York City experienced a surge of robberies of bus drivers in 1968 and 1969, a problem that was almost completely eliminated when drivers stopped making change (and thus did not carry money).

Bus hijackings and hostage incidents are rare occurrences but generally receive wide publicity, hence, they loom larger in the public mind than their statistical occurrence would suggest.

One of the most famous bus hostage incidents took place on June 12, 2000, in Rio de Janeiro, Brazil, and was the subject of the 2002 documentary film, *Bus 174*. In this incident, Sandro Rosa de Nascimento, a former street child, boarded city bus #174, intending to rob the passengers. However, one of the passengers saw that Nascimento was armed and signaled the police, who intercepted the bus.

It became a hostage situation, with large numbers of police and members of the media surrounding the bus, and Nascimento communicating with messages written on the bus windows and shouted out the windows. He let some of the passengers go, but used others as human shields, and faked the execution of one of them. In the early evening, he left the bus, holding one of the passengers before him as a human shield. This hostage, Geisa Firmo Gonçalves, was killed by a combination of bullets fired by Nascimento and the police (she was the only passenger

to die in the incident), while the other passengers were essentially unharmed. Nascimento died from suffocation while in police custody.

Another major hostage crisis occurred in the Philippines on August 23, 2010. A former police officer, Rolando Mendoza, boarded a tourist bus carrying 25 people, mostly from Hong Kong, in the Rizal Park area of Manila. He displayed weapons including a handgun and an automatic rifle and demanded that city officials restore him to his position on the police force. The hostage crisis became a media event, and Mendoza became agitated after seeing this coverage on the onboard television.

After he began killing the passengers, a SWAT team forced its way onto the bus, but the process took about an hour, due in part to the Plexiglass safety windows and the fact that the door could not be forced open. Eventually, Mendoza was shot and killed, but eight bus passengers were also killed during the incident. Investigations by both the Filipino and Hong Kong governments faulted the Filipino police handling of the incident.

Although passenger assault on buses is a rare occurrence in most countries, some serious incidents have drawn public attention to the problem and suggest that they may be more common in the future than previously believed. One such incident was the 2012 gang rape of a woman on a bus in New Delhi, India; her male companion was tied up and beaten until he was unconscious.

The woman later died from her injuries, and the six men who took part in the assault were all charged with murder; one of the assailants, who was also the bus driver, hanged himself in jail. This crime sparked protests across India and drew attention to alleged problems with police corruption and the apparent lack of concern with prosecuting rape cases or otherwise protecting women from sexual assault.

Following the widespread publicity from the New Delhi rape and murder, several sexual assaults on public transportation in Rio de Janeiro, Brazil, also came to public notice. One involved a woman who was raped by an armed assailant on a bus full of passengers, while the driver continued to drive the bus on its normal route.

Another involved a woman who was raped and abducted on a transit van while it drove through densely-populated parts of the city. The perpetrators of the latter crime were not prosecuted

by police, and the same men, using the same van, are accused of repeating their crime a week later, assaulting and raping a 21-year-old female American student and assaulting her male companion.

These crimes drew attention not only to problems with passenger safety but also with a police department and justice system that some charge is unconcerned with assaults on women, and with crimes perpetrated on working-class and poor people. Following the rape of the American student, private transit vans were banned in the southern part of Rio de Janeiro, which is also the most prosperous part of the city, and vans were prohibited from using tinted windows (to make it more difficult to conceal crimes within).

Rail and Subway Accidents and Suicides

In general, rail travel is a safe mode of travel in the United States and other industrialized countries. For instance, in 2007, there were about 43,000 transportation-related fatalities in the United States, and 188 occurred on rail travel, with 124 occurring on commuter-rail operations and another 32 on light rail operations. This comes to about 30 fatalities per 1 million passenger trips for commuter rail, and 8 per 100 million passenger trips for light rail.

Suicides and accidental deaths are far more common on the New York City subway system than homicides, although the latter usually draw more publicity. During a four-and-a-half-year period—2003 to 2007—there were 211 fatalities in the New York City subway system; of these, 111 (52 percent) were suicides, 76 (36 percent) accidental deaths, four (2 percent) homicides, and 20 (9 percent) of undetermined cause.

The most common cause of death was blunt trauma (206; 98 percent), with the remaining five deaths caused by electrocution. The most common cause of accidental death was trespassing on the rail bed or falling onto the subway tracks; a few were caused by falling between trains, by “train surfing” (riding on the roof of a train), or “skylarking” (riding outside the train, hanging onto the doors).

The average age of a person dying in the subway system was 44 years, and 83 percent of those dying in the system were male. Racial and ethnic makeup of the dead was similar to that of New York City as a whole, with 32 percent white, 28 percent Hispanic, 28 percent African American, and 11 percent Asian.

Post-mortem examinations found high rates of alcohol (42 percent) and cocaine (25 percent) in the bodies of those who died accidentally, and somewhat lower rates of antidepressants (21 percent) and alcohol (14 percent) in those who died by suicide. Most suicides occurred during the morning rush hour (6:30 A.M. to 9:30 A.M.), while most accidental deaths occurred between 4:00 A.M. and the morning rush hour.

A 2007 report by the Metropolitan Transit Authority (MTA) on worker death in the New York City subway system revealed that 238 workers had been killed in subway accidents between 1946 and 2007, with half of those occurring before 1960. The most common cause of worker death was being hit by a train while working on the roadbed; other causes included electrocution, fatal injuries in a collision, and being shot during a robbery.

The worst accident in the New York City subway system in 63 years took place on August 28, 1991, resulting in five passenger deaths and over 200 injuries. The cause of the accident was a derailment near the Union Square Station in southern Manhattan caused by excessive speed (over 40 miles per hour in a 10 mph zone). The motorman (who controls the train's speed and braking), Robert Ray, did not report immediately for alcohol testing, but 13 hours later had 0.21 percent alcohol in his blood, far over the legal limit.

Ray later claimed that he fell asleep just before the crash, and he was sentenced to 15 years in prison, of which he served 10 years. The safety equipment in the area where the crash occurred, a system of switch points and trip arms that measure a train's speed and activate the emergency brakes automatically, was found to be working at the time of the accident, but the train was moving too fast to be stopped in time.

Subway Crime

Most subway crimes are minor, including theft, and often reflect the general crime rates in the city where the subway is located and/or the neighborhood in which a particular stop is located. In fact, subway stations are often safer than the streets because of the relatively large numbers of police assigned to patrol them.

Despite these facts, fear of crime in subway stations and on trains seems to be greater than among people who use surface transportation, particularly among women, perhaps because of



A number 7 train pulls up to a platform in New York City. From 2003 to 2007, there were 211 fatalities in the New York City subway system, with 98 percent caused by blunt trauma. The average age of a person dying in the subway system was 44 years, and 83 percent were male.

the enclosed nature of the subway system and the perceived difficulty of escaping from an attacker. Crime in stations is more common than crime on the trains themselves.

The New York City subway system was widely perceived as a dangerous place in the early 1960s, and evidence of increasing crime led then mayor Robert F. Wagner to more than double the number of members of the Transit Police Force from 1,219 to over 3,100. Transit officers were assigned to patrol every station in the system in the evening and early morning hours.

A 1974 analysis by the New York City Rand Institute found that both minor and serious crimes decreased during the hours of patrol, and that crimes also decreased over the other hours of the day as well. In other words, rather than crime being displaced, it was reduced over the entire day. When the special patrols ended, crime did increase, but primarily during the hours that were never included

in the special patrols, with most crime occurring between 4 A.M. and 8 P.M. It is noteworthy that those hours also see much of the ridership, and hence more potential victims are available.

In the 1980s, the subway system was again perceived as dangerous, with public fear and anger focused by the highly publicized case of Bernard Goetz, the so-called subway vigilante. Goetz shot four muggers on a subway train in 1984 and was only convicted of illegal possession of a firearm; some viewed him as a hero for standing up to criminals at a time when the police seemed unwilling or unable to control crime.

One approach by the Transit Authority to reduce crime was a campaign to remove graffiti from all trains, following the “broken windows” theory that the appearance of disorder encourages more crime. Transit police also began a zero-tolerance approach by cracking down on minor offenses such as fare evasion on the theory that people committing such crimes might also be wanted for more serious offenses. Crime did decline by the early 1990s, although the specific reasons for this decline remain unclear because crime declined across the city as a whole in the same years.

Assault and Harassment

In contrast to minor crimes like theft, the most highly publicized incidents in the subway system are usually injuries and deaths to passengers, which are relatively rare occurrences, particularly given the number of people who regularly use the subway (over 4 million daily in New York City, for instance).

In 1999, two separate incidents involving mentally ill people who pushed people from the platform onto the tracks motivated passage of a law allowing New York State to order individuals into involuntary outpatient psychiatric commitment. The involuntary commitment law is called Kendra’s Law in honor of one of those two victims, Kendra Webdale, who died after being shoved in front of a train by Andrew Goldstein, a diagnosed schizophrenic who was not following his prescribed course of treatment. The second victim was Edgar Rivera, who lost both legs (but survived) after being pushed in front of a train by Julio Perez, a homeless man who was schizophrenic.

Sexual harassment, including groping, is a known problem on some subway systems, where crowded cars and the anonymity of the passengers

provide the opportunity for such crimes and may make it difficult for victims to get away or even to identify their assailant. It is difficult to know how frequent the problem is, because many cases are not reported, but it is believed that most victims are female and most assailants male.

In Japan, public groping is known as *chikan*, and due to the perceived extent of the problem, women-only cars have been introduced in some cities. In Egypt, sexual harassment of females is called “Eve teasing,” although some object to that term because it implies that the harassment is mild (“teasing”) or that the women themselves are responsible (in the Jewish and Christian Bibles, Eve tempted Adam to disobey God).

Some cities, including Mumbai in India, now offer women-only compartments on trains in an attempt to shield women from harassment. Other countries with women-only railcars or buses include Mexico, Indonesia, Taiwan, and Israel, although the motivation in Israel is less to reduce crime than to observe customs of separating genders among Orthodox Jews.

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See Also: Security, Transportation; Terrorism, Transportation Systems as Targets of; Transit Systems; Transportation and the Disadvantaged; Women’s Issues/Gender Issues.

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Transit System Technology

Transit system technology is the sum of all historical, contemporary, experimental, and theoretical tools that embody some degree of utility for the planning, developing, constructing, operating, monitoring, upgrading, funding, and administering of transit networks. This technology includes such capital-intensive aspects as train engines and rolling stock, switching yards and dispatcher communications installations, people-mover devices at airports—in short, the vehicles, buildings, and right-of-way improvements that form the physical modes of transit.

The technology also includes such potentially capital-conserving aspects as decision-making software, operations budgeting templates, passenger information display devices, and other information-based, cybernetic, and wireless systems.

Technology Integration

A major force driving the shaping of policy solutions to transit system problems today is the concept of a coordinated methodology and application set, continental in scope, that provides a consistent and economically efficient guide to the infrastructure and operational systems of mass transportation. By standardizing transit system technology and its administration, by incentivizing wise policy implementation, and by funding research and application of more efficient technologies, such programs can lead to the adoption of smarter systems by a growing number of municipalities and regions.

Through the Intelligent Transportation Systems Joint Program Office of the U.S. Department of Transportation (DOT)'s Research and Innovative Technology Administration (RITA), for example, challenges such as corridor congestion and intermodal exchange are receiving some of the first directed attention and research funding. RITA directives such as its Integrated Corridor Management (ICM) program are slated to translate from research into better-planned and more effectively operated metropolitan and regional transit systems.

One element illustrative of the ICM approach is the Clarus initiative, by which extensive real-time weather reporting and forecasting data is compiled, sorted, and categorically ramified, the results being disseminated to users with diverse needs across the transit spectrum. Five components of Clarus show how the results can serve different user bases that together ease congestion and reduce hazards across a given transit system:

1. Enhanced road weather forecasting for all surface transit modes
2. Seasonal weight restriction decision-support tool for trucking and rail
3. Nonwinter maintenance and operations timing support
4. Multistate surface mode control strategy support
5. Enhanced road weather content for travel advisories

As a result of testing and tuning of the Clarus system in the 13 U.S. states and three Canadian provinces that began in 2004, the U.S. Federal Highway Administration (FHWA) identified specific means

“to foster collaboration between transportation engineering, computer science, and atmospheric science disciplines” toward the goal of using data to improve transit operations management and create innovative interfaces within and between transit agencies.

FHWA then awarded eight contracts as of 2011 for the development of data integration, visualization tool improvement, alert system upgrades, mobile applications, and related technologies. These applications are coming online for use by trucking companies, bus systems, urban and rural motorists, emergency response and police departments, road crew managers, transit system operations centers, insurance companies, and other user bases in the United States and Canada.

Specific to congestion problems, the ICM system combines and connects data and management tools across four major areas of transit: rail systems, bus systems, freeway systems, and arterial signal systems. The research approach is to develop both information and hard infrastructure technology that together can yield a better informed, time-sensitive, and conditions-predictive operations management and user base across all modes in a given transit corridor that has been identified for comprehensive improvement.

The ICM policy and its successful adaptations to local realities depend upon the active participation of the diverse parties involved, such as local jurisdiction agencies that operate traffic signal systems, regional rail agencies operating train management systems, state transportation bodies managing flexible freeway access and traffic flow, and bus companies utilizing automatic vehicle location systems. Technology transfer among such parties is facilitated by their dedicated engagement within a regional ICM working group, partly funded under federal auspices via the FHWA and sister agencies.

ICM embodies a full catalog of management and operational standards for each transit mode and for the real-time exchange of data between the agencies monitoring and controlling each mode. The standards continue to develop under the guidance of such bodies as the Institute of Transportation Engineers, the American Public Transportation Association, and similar groups. The ICM standards embody aspects as diverse as data sharing protocols, signal and sensor device metering, and signal control prioritization.

ICM further utilizes ongoing improvements in data gathering, display technologies, electronic credentialing, targeted automated screenings, and intermodal data sharing in order to advance both passenger and freight transport management. The freight area in particular involves even more modes of transit, with its focus on multimodal exchange, international border operations, maritime applications, and commercial vehicle information systems and networks that are available to both private and public users.

Intelligent Transit

Ideally, the heavy infrastructure and the information components of a transit system work together to form what is called an intelligent transportation system (ITS). One such system that today exists in a status somewhere between the theoretical and the widely practical is the connected vehicle environment. There are numerous large interested parties—from the federal government’s DOT to private concerns including Google, Inc.—that are committing significant resources to research and develop this type of intelligent transportation system.

As envisioned, it will comprise private and public motor vehicles linked via wireless communications to a hybrid centralized-distributed monitoring and control system that provides safe and secure remote-assisted guidance and vehicle spacing during normal operations on designated public roadways. (This is not a “driverless car” scenario, but it does incorporate some aspects of driverless technology.)

It is conceived that the connected vehicle environment will deliver benefits including enhanced driver and passenger safety, greatly increased roadway capacity, reduced congestion, significant fuel and energy savings, cleaner environmental conditions, and household economy savings, as well as job growth through automotive and telecommunications industry expansion, related intermodal transit improvement, and streamlined regulatory functions.

On the government’s part, the research into this mode of transit is being spearheaded and coordinated by RITA. Mandating that the system be “national in scale and extensible across North America,” RITA is particularly dedicated to safeguarding the leading priority of all DOT programs—safety.

Yet, in the working statement of purpose for this project, RITA notes that other uses of a connected

vehicle environment, “especially for mobility and environmental purposes, are permissible and encouraged as long as they do not detract from safety.”

RITA documentation also notes that the connected vehicle environment must use dedicated short-range communications (DSRC) technology unless or until an equivalent system is devised that tests to be at least as safe as DSRC. The rollout of DSRC goes beyond this very early-stage pursuit of a connected vehicle environment application, however. DSRC is the choice by DOT for all “active safety” operations involving vehicle-to-vehicle and vehicle-to-infrastructure applications.

It is interesting to note that, by virtue of this type of advanced technology, DOT and private enterprise are teaming up to transform the heavily energy-intensive and individual-vehicle-based national highway system into an intelligent system that, over time, could become a true mass transit alternative and part of a new network of connected intermodal systems.

Near-Term Systems

Transit system technology that is already in broad use, or close to widespread adoption, includes solutions and tools that make it possible to operate transit functions such as service scheduling, capacity and speed control and monitoring, system analysis optimization, station location supply and support, fare economics modeling, ridership management, financing, regulatory compliance, selection of performance levels, and selection of transit modes.

The bulk of these functions at one time were conceived, built, and operated in-house, within a straightforward hierarchy of authority and responsibility. In contemporary transit system management, however, the information technology must be designed to, in a secure and organized fashion, facilitate exchanges between stakeholders who maintain great differences in priorities. These include private enterprise contractors, consumer and merchant organizations, metropolitan planning organizations, real estate management companies, funding entities, and regulatory oversight panels at the regional, state, and national levels.

On the hardware side of the transit equation, equipment designers and engineers around the world are moving forward on many fronts with some progressive goals—some mandatory, others voluntary—that are somewhat universally prized.

For instance, the ideal of sustainability, that transit vehicles and infrastructure must be built and operated in ways to minimize energy waste and environmental degradation, is virtually inarguable. This single principle, so widely accepted, already has driven some very practical outcomes in transit system technology decisions.

In the Denver, Colorado, metropolitan area, for example, city and regional authorities took great pains to work with academic researchers, government advisers, and private industry contractors to devise an integrated multimodal transit network to meet the area’s growing mobility needs for decades to come. The process is being managed by the Regional Transportation District (RTD), the main transit planning and operational body for the area.

Throughout this process, environmental sustainability was near the top of all priorities; related constants were the need to abate and mitigate noise pollution and support better air quality.

The resulting system, called FasTracks, embodies that principle of sustainability across all modes: light rail, commuter rail, bus rapid transit, and streetcar transit. Each mode was selected for particular zones and to fill specific transit need niches. Each mode is being installed and built out in accordance with its projected contributions to system-wide metrics.

The managers for each of the modes are purchasing and deploying technologically advanced infrastructure and vehicles designed and modified for specified levels of rider comfort, line capacity, transit speed, and other metrics, within the overall system budget requirements.

The application of goal-directed planning and budget processes to the FasTracks system does not stop at the doorstep of an express bus or on the station platform of a light-rail train, however. With true “system” awareness, FasTracks and RTD incorporate a holistic approach to the transit network.

This means that transit-oriented development (TOD) is applied to areas in the vicinity of system lines and stations. TOD is an approach to transit system development that takes into account the options for neighborhood improvement and economic stimulation that arise during major build-outs of transit systems. Property values, parking, congestion, pedestrian amenities, and many more urban considerations are accounted for in this approach. By applying the TOD principles, the

transit authorities seek to gain such benefits as the following:

- Reducing sprawl and protecting existing neighborhoods
- Reducing commute times and traffic congestion
- Improving environmental quality and open space preservation
- Encouraging pedestrian activity and discouraging automobile dependency

Each of these principles helps transit system developers refine their applied techniques, which in turn lead to more intelligent, sustainable, and value-enhancing decisions regarding technology.

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See Also: Automated Transit Systems; Intelligent Transportation Systems; Transit Industry, Economics of; Transit Systems Analysis; Transportation Planning.

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Transit Systems

Mass transit, public transport, and public transportation—all usually synonymous terms—refer to transportation services that are typically provided by a government entity and available to the general public.

Transit is different from services such as taxis that are not available for simultaneous use by multiple members of the public (vanpools present one notable exception). Transit services generally charge a fee for use and operate according to a published timetable.

In most of the world, essential public transport services are provided by units of government as a public or social service. While such services are expensive to operate, and most transit systems operate at a loss and require public subsidies, many scholars and activists argue that safe and reliable mobility options are essential to a functioning society. Other scholars, however, point out there is nothing inherently universal about public transit, and its usefulness to society is fungible rather than essential.

While there have been notable examples of privatized forms of public transportation in recent world history, most fail to sustain themselves financially without significant public investment in infrastructure or outright subsidies by governments.

Because the most fundamental infrastructure resources of public transportation—roads, sidewalks, turnouts, benches, and bus stops—are publicly owned, in addition to the need for subsidies to

remain solvent, the vast majority of transit agencies are publicly owned and operate with a monopoly on a geographical area.

History

While the history and origins of all modes of public transport are not completely known, water taxis, a boat for water crossing available for a fee, are the first known forms of public transportation. Ancient Greeks were said to bury their dead with a coin under their tongues for fare on ferries to take them to Hades.

North American public transport also revolved around water-based forms until the early 1800s. Horse-drawn carriages were introduced in New York City in 1827 and expanded to include a horse-drawn railway in 1832.

Cable cars, as popularized today in San Francisco, California, were the first mechanized public transport vehicles in 1873. While a number of cities—including Chicago, Illinois, and New York, New York,—utilized cable cars, only San Francisco's system remains. Cable cars were soon followed by electrically powered streetcars, first used in Richmond, Virginia, in 1888.

Boston, Massachusetts, and New York City opened subterranean subway systems in 1897 and 1904, respectively, but streetcars operating in public rights of way and sharing their route with other forms of transportation, became ubiquitous in North American cities in the first decades of the 1900s, eventually used in 370 U.S. cities by 1912.

Except for those in Seattle, Washington; Detroit, Michigan; San Francisco; New York; and Boston, practically all transit companies were privately owned, and most were forced into bankruptcy in the 1950s and 1960s as suburbanization became the primary form of development, the population in cities plummeted, and Americans' love affair with the private automobile grew exponentially.

Transit, unable to compete with major public investments in roads and highways, fell from its high of 23.4 billion passengers in 1946 to just 10 billion a decade later. Cities all over the United States scaled back or canceled public transit expansions. By 1970, only seven streetcar systems remained in cities, including San Francisco, New Orleans (Louisiana), Newark (New Jersey), Boston, Cleveland (Ohio), and Philadelphia (Pennsylvania), and public transit ridership had further fallen to 7.3 billion.



Two streetcars running parallel to each other on Canal Street in New Orleans, Louisiana, in May 2013. Unlike light rail systems, streetcars often share a roadway with other traffic.

Responding to the bankruptcy crisis threatening transit systems all over the country, in 1964 Congress passed the Urban Mass Transportation Act, which provided grants and loans for cities and states to purchase these struggling, privately owned transit companies and operate them as public agencies.

The act also created the Urban Mass Transportation Administration (which would become the Federal Transit Administration [FTA] in 1991) to oversee and regulate transit agencies receiving federal funds. President John F. Kennedy and Congress saw public transport as a way to mitigate traffic congestion, worsening air pollution, sprawling land use development patterns, and the physical and social isolation of those unable to operate a private automobile.

Public investment in transit helped stabilize transit ridership, increasing from a century low of 6.5 billion passengers in 1972 to 10.2 billion in 2010.

Transit agencies in the United States employed just under 400,000 individuals in 2010.

Modes

Presently, there are a variety of modes, or types, of public transport vehicles: airplanes, buses (including trolleybuses), water ferries, and rail (streetcars, light rail, heavy rail, and commuter rail). All use some form of infrastructure, whether roads, airports, seaports, tunnels, or fixed guideways (for example, rail tracks or overhead electric cables).

According to the American Public Transportation Association, as of 2010, only one U.S. metropolitan area uses cable cars, 35 utilize light rail, 51 provide ferryboats, and 676 maintain bus systems. Each mode is discussed below.

Buses, first introduced in 1922, began to replace streetcars in many U.S. cities by the middle of the 20th century. Transit providers preferred the rubber-tired vehicles because of their lower start-up costs, but primarily because of the ease with which they could be re-routed to serve new or different neighborhoods.

Public transportation buses can serve locales of any size, provided they have roads. The United States' 66,239 public buses carried 5.2 billion passengers in 2010, over half of all transit riders, but roughly half the 10.7 billion passengers they carried at their peak in 1948. Buses continue to be the "workhorses" of the nation's transit systems, operating at longer distances and for longer hours than any other mode.

At an average speed of 12.9 miles per hour (mph), however, buses are also one of public transport's slowest modes because they generally do not have their own rights-of-way and are dependent on external traffic conditions. In contrast, bus rapid transit (BRT) operates with its own dedicated right-of-way and automated traffic signals giving buses priority, thus maintaining higher speeds. This relatively new form of bus service was first deployed in the United States in Los Angeles in 1973 and is beginning to become more popular in other global cities, including Mexico City, Mexico, and Johannesburg, South Africa.

Buses can be powered either by onboard fuel (most often diesel) or by electricity via overhead electrical lines. These vehicles, known as trolleybuses, are occasionally differentiated in literature on public transportation. Buses occupy a notorious

position in American culture, inextricably linked with poverty and users who have no better mobility options.

There are different types of railway transport: light rail, heavy rail, commuter rail, and streetcars. Distinctions between the types are frequently vague, but railways in general refer to a family of public transport vehicles designed to operate on fixed, guided, steel rails and, with the exception of streetcars, in exclusive rights-of-way. Rail systems, unlike bus systems, must build and maintain their own tracks, stations, and rights-of-way.

Light rail and streetcars, as opposed to heavy and commuter rail, are intended to be constructed relatively quickly, serve more frequent stops, and require a smaller investment in infrastructure because of a lower weight load. Light rail, utilizing its own right-of-way, generally operates at street level (for example, Minneapolis, Minnesota's Hiawatha Line).

Streetcars, also at street level, share the roadway with automobiles and, occasionally, pedestrians (for example, New Orleans' Canal Street streetcar line or Portland, Oregon's Tri-Met's streetcar line on the Portland State University campus).

Both light rail and streetcar vehicles can operate singularly or in tandem with multiple vehicles to accommodate different passenger loads. Light rail in the United States in 2010 carried 457 million passengers, up from 320 million in 2000. Thirty-five U.S. cities use some form of light rail public transport, up from less than 10 in 1970; these services average 15 mph when in service.

Heavy and commuter rail, collectively known as rapid transit, refer to high-capacity, high-speed systems, operating entirely in their own rights-of-way. Heavy rail, more popularly known as a subway, is built underground about 50 percent of the time (for example, the Bay Area Rapid Transit [BART] subway in San Francisco, California, or the London Underground), 20 percent of the time on elevated tracks (for example, the Chicago Transit Authority's CTA's "L" trains), and the remainder at ground level.

Commuter rail (for example, Nashville, Tennessee's Music City Star) frequently shares tracks and infrastructure with freight rail lines—being built at ground level 90 percent of its length—and typically serves widely spaced suburban stations with extensive park-and-ride facilities. Twenty-eight U.S. cities with commuter rail transit—up from less than

10 in 1970—carried 464 million passengers in 2010 at an average of 33 mph, the fastest of all modes of public transport.

Fifteen U.S. metropolitan areas with heavy rail systems—up from 10 in 1970—collectively carried 3.5 billion passengers, roughly equivalent to the number of passengers on Tokyo's subway alone. Heavy rail in the United States operated at 20 mph, on average, the second highest speed among modes.

Ferryboats, used in 51 U.S. metropolitan areas, represent the oldest form of public transport in the United States and world. They are also the largest public transport vehicles and the slowest, at just under 10 mph. However, ferries can greatly shorten distances ordinarily traveled around bodies of water. Ferries are capable of carrying passengers, and some transport automobiles, too, blurring their distinction as public transport.

In 2010, ferry boats in the United States carried 90 million passengers, half of which occurred within just two transit agencies, Washington State Ferries and the New York City Department of Transportation.

Fares

On all but a few public transport systems in selected cities in Europe, and with the exception of discounts provided to certain populations, most public transportation services are provided for a fee that each passenger pays at the time of service, either with cash or a prepaid card.

Fares usually constitute a fraction of the actual cost of the service, and the ratio of the fare to the actual cost is known as the “farebox ratio.” The higher the farebox ratio, the lower the subsidy provided by taxpayers, but users may also be paying a higher fare than on comparable transit agencies. On average, most transit operations receive 55 percent of their funding from direct government assistance, with the remainder obtained through fares, advertising, leasing arrangements, or other sources.

Fares on public transport in the United States totaled \$12.5 billion in 2010. Agencies, while bound by local or state regulations, are able to charge fares as they see fit, and there are distinctions between the ways fares are assessed. Some agencies charge a fixed fare, in which passengers pay the same fare no matter how far they travel. Other agencies charge fares based on length of travel or by assessing geographic zones that differentiate fare costs.

Some social justice advocates claim fixed-fare policies unfairly shift fare burdens from suburban populations, who typically travel longer distances to inner-city populations, typically poorer than their suburban counterparts and who travel shorter distances. Zone-based fare structures, however, can be difficult to administer and collect, and some argue they lead to higher costs for all riders.

Funding Controversies

A number of transportation scholars point out that while 20 percent of all federal transportation funds are spent on public transportation, most states fund it at much lower levels—sometimes offering nothing to public transportation agencies. In spite of the fact that over 20 percent of African American, 15 percent of Hispanic, 13 percent of Asian American, and 7 percent of white households do not own a car, transportation funding at the state level tends to accrue for the benefit of private automobile owners.

Further, when differentiating among public transport agencies around the country, heavy and commuter rail services, more often used by suburban and more affluent patrons, are subsidized at significantly higher rates than bus services, effectively lowering costs for rail users at the expense of bus riders. Commuter rail, the public transport mode of choice for whites, is subsidized at far higher rates than bus systems, which are primarily used by poor Americans of color.

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See Also: American Public Transportation Association; Bus Rapid Transit; Buses; Commuter Rail; Ferries; Heavy Rail Transit; Light Rail Transit; Streetcars/Trolleys; Transit Demographics; Transit Dependence; Transit Fares; Transportation Policies, North American.

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Transit Systems, Marketing Research and Public Relations for

Marketing is strictly the science of determining what consumers are willing to buy and how much they will pay, and, therefore, marketing planning should be an important part of the planning of any transit improvements. Through the marketing planning process, improvements that will be used can be identified, and an assessment can be made of the economics at the price consumers will pay.

The science of potential customer feedback is well established in the domestic consumer industries, where prototypes of new products can be shown to consumers, who are asked for evaluation. Clearly, this is not usually practical for a new transit service. Spending time at an early stage can help transit authorities avoid wasted expenditures on a service that will not be used by enough people to be economical, or that will need expensive retrofitting to overcome problems that could have been identified and designed out before construction began.

Launching a New Service

Once a decision has been reached on implementing a transit improvement, public relations (PR) and advertising come into play. PR is about handling issues, usually complaints, personally addressed to the transit body or its agents.

Many companies use PR as a surrogate form of marketing and studiously reply to every complaint. Follow-up studies have shown that feedback to such complaints is shared positively by the complainant with about 20 friends and family, creating a good image for the organization. No response or negative responses to complaints have the opposite effect.

"The medium is the message" wrote author and academic Marshall McLuhan. Often, low-cost advertising is more effective at raising consumer awareness than expensive media, such as television. The most effective advertising is personal recommendation but getting that is a real challenge when a new service is launched.

Almost everyone needs to travel, and so this can be the starting point for a launch. Most journeys are made by car, so the launch needs to get people to consider the transit option for particular trips. Usually, there will be a "pre-launch teaser" advertising campaign. This can include incentives to encourage people to contact an organization for information or a prize in return for registering their personal contact information, including, where possible, mobile phone numbers. Advertising through cell phones is now an important communications tool.

Adults are also influenced by their children's pestering them. Getting a message to children through public education programs in local schools, for example, can build awareness in families and communities with messages supporting transit. Children are often environmentally aware, so a transit is "green" message can be a powerful way to get families to try the new service when introduced. Developing competitions for children (for example, coloring or essay contents) as part of the launch, together with introductory discounts, can be a first step to getting a new generation to choose public transit.

Teenagers are the most mobile sector of the population, and many resent having to be taxed by parents, which explains the importance of the rite of passage in gaining a driver's license. Teenagers also have disposable income and are often environmentally aware. If the new transit service is marketed to teens as an option for travel "freedom," this could be a big attraction, especially if it includes riding with groups of their friends.

Why People Do Not Use Transit

This can be a killer question, because getting more users and building a wider clientele is key to

ensuring the success of a new transit service. Market research targeting non-transit riders can be illuminating. Responses range from factual (there is no transit service available) to emotional (it is not good enough, or I don't like the people who are riders).

Factual reasons for not riding transit can be addressed. For example, people often think that transit is too expensive, without realizing how expensive it is to own and drive a car, especially when fuel is only bought infrequently with a credit card, so the cost does not register for a particular journey. Most European transit services now sell travel by time, with tickets available for unlimited trips for one hour, one day, one week, one month, or one year. Such tickets can be automatically paid directly from a bank account or from a cell phone. Emotional reasons can be more difficult to address. There are many examples of advertising campaigns, though, that have addressed emotional issues indirectly.

One example occurred in the city of Brussels, Belgium, where transit patronage had been falling for some time. Market research showed that part of the reason was that ticket inspectors with military-style uniforms were seen to be a quasi-gestapo. This led to a long poster campaign displaying the ticket takers in a new "softer" uniform that had been introduced in response to the market research. The posters featured the faces of different inspectors with captions such as "Uncle John here to help you get safely home."

Within six months, public attitude to transit in Brussels improved, and after one year, patronage started to increase, and this has been the case ever since. Growing patronage also provides transit agencies with confidence to invest in new services, which then reinforces the image that transit is progressive.

Addressing Negatives

There are negatives as well as positives to public transit. Transit may not be convenient, it may not serve the places to which many people travel, and it could be perceived as too slow, too expensive, too dirty, unsafe, or unfriendly. Some of these perceptions can be misconceptions, although they may be difficult to overcome.

There are direct and indirect ways in which negative perceptions can be addressed. The direct ways include the usual advertising and promotional methods. The indirect ways include working with

producers to have transit travel and/or locations written into TV series, featured on TV news, or mentioned by opinion leaders in press articles or on social media. The latter can be facilitated by special press events and tours.

PR in a Crowded Media World

Transit is not the only product vying for the attention of the public. Countless commercial products and services, from consumables like food and drink to durables like cars and home appliances, are advertised to consumers with huge budgets on television, radio, the Internet, billboards, newspapers and magazines, and even public bathrooms.

In contrast to consumer goods, transit is a public good that confers benefits to individuals. Although getting that complex message across can be difficult and expensive, it is vital if the transit "product" is to be properly positioned in the consumer marketplace.

Developing the Positives

Transit is green (that is, environmentally beneficial), which is an important characteristic in these environmentally conscious times. Streetcars, subways, light rail, and trams are proven to attract people away from their cars, at least for certain trips, such as commuting.

Most businesses depend on repeat customers. For transit, the daily commuter is an example of a repeat customer. With its spikes of peak usage near the beginning and end of the workday, though, daily commuters place the greatest economic strain on the cost of transit operations, with a large capacity required for only about 20 percent of the weekday. At other times, there is spare capacity, which effectively has an almost no marginal cost of operation.

This pattern provides an opportunity for transit services to attract off-peak trips by lowering fares or creating special deals, such as pairing a transit fare with tickets to entertainment or other leisure activities. Transit also can be a very sociable mode of transport, so clubs, schools, and informal groups can be encouraged to travel off-peak, especially if transit is linked to an activity at the journey's destination.

Case Studies

In 1979, the newly formed transit cooperative company in the Rhine-Ruhr region of Germany changed

its fare system from paying by distance traveled to a flat fare, with an average fare increase of 10 percent. This change was preceded by advertising on billboards and leaflets delivered to homes and distributed at transit stops explaining how the new fare system would work. Based on past experience, a 10 percent increase in fares was expected to result in a 3 percent decline of patronage but a 7 percent increase in overall revenue.

Much to everyone's surprise, patronage grew by 4 percent after the change, resulting in a revenue increase of 14 percent, much larger than the budget. This extra revenue was then reinvested in service improvements, which started a self-funding virtuous cycle of rising transit patronage and revenue.

Why was this counterintuitive experience achieved? Analysis of passenger attitudes showed that the advertising campaign had for the first time presented a positive image of transit, with a new product implying confidence in the service. This was reinforced by the use of colloquial language and avoidance of "officialese."

In 1986, bus services in the United Kingdom were deregulated. From 1933 until that time, all bus services had been tightly controlled, effectively giving operators monopoly rights for large areas in return for running socially necessary but unprofitable services, cross-subsidized by profitable trunk bus routes.

While this was an acceptable solution in 1933, when most people were transit dependent, that was not the case in 1986, when bus services were heavily subsidized by the state. With deregulation, bus companies could run any service at any time in a competitive market on a purely commercial basis. In the run-up to deregulation, a number of new bus companies were formed.

One of these was the BeeLine Buzz Company, which planned to run minibus services at high frequency along a few key routes in Manchester. BeeLine targeted teenagers and, as part of its promotion, had a billboard campaign along the intended routes. T-shirts were also given away at schools and youth clubs with the company name and logo.

The incumbent bus company answered this with a series of expensive TV commercials. Once running, BeeLine soon built up a substantial patronage, which forced the incumbent bus operator to reduce services. Market research follow-up six months after the BeeLine service began showed a

very high recollection of the original bus company's TV advertising campaign—but most respondents thought it was for BeeLine. While the big bus company wasted its money, little BeeLine became the market leader.

In Basel, Switzerland, a "Rainbow" monthly discount ticket was launched with the aim of attracting commuters who would leave their cars at home and use transit instead. Although the ticket was set at an attractive fare, a slight loss was budgeted because the expected increase in ridership would also increase peak capacity. In practice, though, double the number of drivers forecast signed up for the Rainbow ticket, resulting in the operator making a surplus. Meanwhile, because of the reduced road traffic and congestion, the operator was able to increase peak capacity without any extra costs.

The Right Medium as the Message

As the case studies above demonstrate, effectively getting the transit message across does not need to be costly if the right medium is used and the message is credible. To get the message right requires both market research and product improvement, which should involve the feedback of both existing passengers and those who do not ride transit. A strong and growing medium combines personal communications and social media in the form of cell phones connected to services such as Twitter, Facebook, Instagram, Tumblr, and others. Indeed, these media allow the transit operator to tailor the message to both existing and potential riders.

How can transit agencies reach cell phone users? Existing riders can be given an incentive, for example, to pay by cell phone through a downloadable application. Potential riders could be courted through a teaser campaign with a big prize offering, such as an all-expenses-paid vacation. The cost of the prize could be small compared to the awareness and access to market research data that can be obtained.

The Message

A transit operator able to boast that ridership is growing has a strong message for nonriders: "What are you missing?" Messages also can target taxpayers who underwrite transit in many cities. Using social media, agencies can receive rapid feedback on the effectiveness of the message, which can be adjusted to resonate with that feedback.

Selling the Transit Product

While a majority of people need to travel for work, school, shopping, health care and other reasons, most people have considerable choice over their mode of transport and the time of travel. The personal car gives people the ultimate convenience and travel flexibility. This, of course, breaks down when the car becomes a mass mode of travel and the society has neither the funds nor the willingness to devote large parts of urban areas to provide enough road capacity to allow noncongested driving at peak times.

Transit can play a role in keeping cities civilized, but transit must be provided in a form to which car commuters are willing to switch. As many cities have shown, attracting car commuters to transit allows road capacity to be reduced and released for other value-added activities, or even converted into green space. This can be a major benefit to the whole community (for example, by reducing local taxes or providing better services).

Therefore, a partnership between the transit operator and city hall is needed to find the best way to attract car trips, allowing the operator to sell transit services to an increasingly willing population.

An example of how this can be achieved was the referendum required to raise the sales tax in Dallas, Texas, to enable the first Dallas Area Rapid Transit (DART) line to be built in the 1980s. A follow-up study asked people why they had voted to increase their taxes. The message was that "DART would get other car drivers off the road and make my commute quicker."

In many consumer industries, up to 10 percent of revenue is devoted to advertising and promotion. Few transit operators manage 1 percent. Indeed, in the United Kingdom, for every dollar the transit industry spends on advertising and promotion, the automobile and related industries spend \$100. In the absence of such a large budget, transit needs to be smart in its approach, especially by targeting key urban population sectors.

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See Also: Commuting; Noncommuter Travel; Transit Fares; Transit Industry, Economics of; Transit Ridership; Travel Pricing.

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Transit Systems, Service Quality of

Transit systems provide a mobility alternative of fixed and scheduled routes, which jointly induce network effects. The economies of scale, the increasing returns to scale, and the efficient space utilization associated with transit systems make them an efficient and effective means of transport that yields benefits to individual travelers, as well as social benefits to the community.

Furthermore, transit systems can contribute to more sustainable transport overall by reducing car congestion, emissions, and energy consumption and improving traffic safety and social inclusiveness. Thus, the improvement of level of service (LOS) of transit systems is always an important agenda of stakeholders and transport providers.

Regardless whether transit systems are considered a public good or market product, or anything along this spectrum, service quality is an important determinant of a system's attractiveness and, hence, influences the transit market share. Therefore, the underlying administrative and operations environment should support a quality-oriented service development.

Determinants and Indicators

In measuring their accomplishment in providing good services, transport authorities and providers use many standardized indicators based on their

passengers' travel satisfaction, such as comfort, value for money, punctuality, and so forth. Because those passengers have basic requirements that need to be fulfilled, the customers will be extremely dissatisfied if these requirements are not fulfilled.

On the other hand, the customer takes these requirements for granted, and so their fulfillment alone will not increase satisfaction. While fulfilling these requirements will only lead to a state of "not dissatisfied," they are regarded as prerequisites and are in any case a decisive competitive factor.

Based on the extensive literature on transit LOS, the following service aspects have been identified as important determinants of service quality:

- *Accessibility*: Providing a universally accessible service with respect to geographical coverage, social inclusiveness, affordable service, and minimal physical and mental barriers.
- *Availability*: Enabling customers to rely on transit services throughout the day and week, and to enable them to carry out daily activities by providing reasonable service frequency.
- *Ease-of-use*: A user-friendly system allows travelers to acquire relevant and timely information, help them orient themselves in the system, and pay with a simple ticketing scheme and fare collection solutions.
- *Directness*: In order to be competitive, transit service must provide a reasonably direct connection at a good speed when compared with alternative travel modes.
- *Reliability*: The delivered transit service should adhere to the planned service schedule as much as possible. This implies a punctual and regular service that meets the expected duration of the journey with no cancelled or delayed services or overcrowding.
- *Connectivity*: A well-connected network facilitates seamless transfer between lines, as well as other modes of transport. The main determinants of connectivity quality are clear directional guides, information, timetable coordination, facility design, and a common ticketing system and linkage with access and egress modes.
- *Convenience*: Service comfort depends on waiting and onboard conditions, including the following service dimensions: temperature, amenities, service, crowding, and driving smoothness.
- *Appeal*: The perception of service quality also depends on transit stop or station and vehicle design, as well as fleet age, cleanliness, branding, staffing, and fellow travelers.
- *Safety and security*: Service quality depends on a low perceived risk with respect to intentional attacks, crime, technical failures, and health impacts. The sense of safety and security depends on lighting, staff presence, surveillance systems, and the absence of other health-threatening factors.
- *Responsiveness*: The ability of the transit system to adapt itself to changes or unexpected events includes offering replacement service and addressing customer care inquiries.

The manifestation of the quality aspects mentioned above depends on the integration of transit systems in urban and regional development planning, as well as on information and communication technologies (ICT) advancements. The interface between transit systems and the geographical distribution of activities is fundamental to service quality.

The implementation of advanced public transport systems (APTS) facilitates new mobility solutions and services. In particular, the availability of real-time information, Internet connection, and other ICT enhancements can reduce the perceived waiting and in-vehicle times.

The minimal quality requirements of transport services are usually set in the contractual relationship between the public transport authority and the transport operator. The requirements describing the acceptable quality level usually derive from the national transport policy. Thus, transit authorities are delegated by the respective political bodies to guarantee a minimum level of transport service quality is met. These requirements include the following:

- Accessibility, the maximum walking distance from each facility to public transport service



Connectivity is an important aspect of determining the quality of service offered by a public transit system. Passengers want to be able to transfer between lines seamlessly, which makes clear directional guides, timetable coordination, and updated connectivity information extremely important.

- Availability, in terms of public transport trips per hour (frequency) and the service span (length of operation within a 24-hour period) as a function of the development area size and its location
- Crowding level, the level of standing capacity utilization on the busiest trip
- Reliability, expressed either in terms of punctuality—deviation from planned timetable—and/or regularity, which is the deviation from planned headway between consecutive vehicle arrivals

Measuring the Quality Indicators

The rapid increase in deployment of geographic information systems (GIS) and automatic data collection methods (ADC) in the transit sector enables

the generation of various quantitative quality indicators based on extensive empirical data. In some cases, quality indicators might even be available in real time and support supply-and-demand management strategies.

Benchmarking is increasingly used as a tool to analyze and compare various quality measures across stakeholders in the transit industry. The comparison facilitates the identification of problem areas, priority areas for improvement, and ways of sharing information regarding best practices. It is common practice to carry out satisfaction surveys on a regular basis in order to monitor and evaluate perceived service quality. The results of such surveys are often embedded in the contractual incentive agreement.

The values of these quality factors among public transport users (and potential users) can be measured using stated-preference surveys (where respondents state how much they value a particular feature) and revealed-preference studies (based on observation of the choices people actually make when facing trade-offs between various attributes). In conventional planning practices, qualitative factors, such as travel convenience, comforts, and security, were translated into monetary values.

It should be stressed that the subjective nature of perceived service quality implies that it is subject to contextual and cognitive biases. Measurements of service quality based on reported satisfaction levels are therefore dependent on travelers' expectations, social norms, and retrieved situational awareness.

Why does this matter? Experienced utility directly reflects satisfaction with the service level of transport. In transport planning aiming to improve the service level, it is therefore advisable to measure experienced utility instead of, or as a complement to, decision utility inferred from choices. Without this knowledge, there will be no reliable answer as to which of the two notions of utility really matters in making real impacts for customers and potential customers.

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See Also: Benefit–Cost Analysis of Transportation; Levels of Service; Transit Performance Monitoring and Evaluation; Transit Systems, Marketing Research and Public Relations for; Travel Choice.

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Transit Systems Analysis

Transit systems analysis is a discipline employing various methods and technologies to acquire, compile, measure, monitor, and analyze data related to the performance of passenger transportation modes and networks. Typically, it is a function focused on public transit operators and is carried out either by those operators, by outside auditors, or by government agencies specifically tasked with researching and implementing improvements and modifications to public transit.

Beyond the actual physical inventory and physical performance metrics of the transit system's installed base, systems analysis usually also examines the human resources profile, decision-making flow, telecommunications and technology support infrastructure, fare- and fee-collecting performance, budgetary priorities, debt and financial status, fiscal compliance, and reporting requirements.

Broad Mandates

Public transit systems analysis provides transit systems authorities with a means to continually gather and utilize data needed to monitor management performance and guide decision making. It also provides the information output needed to adequately report to government oversight agencies, funding sources, insurers and legal claims boards, tax panels, and similar bodies.

Systems analysis for transit operators is vital in order to contrast and compare the performance and quality of a particular transit network with those of

networks in other jurisdictions. It is also vital for the twin needs of providing lawmakers with clear and verifiable feedback on transportation initiatives, and providing procurement management and staff with time-sensitive parts, equipment, personnel, and expertise needs so that appropriate contracts, invoices, and payment schedules can be supported.

All of these forms of utilization of various data streams are in essence mandates that must be fulfilled by the transit systems' analysis team and its tools. Without accurate and timely data, not only is the ongoing smooth operation of a transit network in jeopardy, but the future status of the network can be placed in doubt when the planning process is set back by missing, inaccurate, or misleading information.

Implemented, upcoming, or potentially available state and federal grant programs are one example of the type of critical financial support that cannot be obtained or sustained without provision of required data. The ability to research, attract, apply for, secure, deploy, and administer such critical funding resources is a core competency in any major urban transit agency or state or regional department of transportation.

Systems analysis helps support these efforts, directly affecting the agency's capacity to purchase rolling stock; improve byways; gain needed services for elderly, disabled, and indigent citizens; and other necessities. The data sets can also help make the case for the fiduciary or consulting assistance needed to assess the network's long-term soundness, to improve its accessibility, to develop partnerships with other public authorities for such projects as intermodal and regional transit links, and to forge mutually beneficial relationships with private entities.

Operational Oversight

In the ongoing, day-to-day operations of a transit system, managers need to dependably "look over the shoulder" of dispatchers, drivers, engineers, mechanics, conductors, ticket agents, safety and security officers, and other employee and associate categories of workers. The productivity of each individual, group, category, location, and department must be monitored, maintained, reviewed, and, if possible, improved.

The on-the-job decisions and actions taken by any one category of transit workers is likely to affect the conditions and situations faced by all

other workers. For example, the dispatchers' decision making on rescheduling to adhere to hourly carrying capacity goals and requirements on a particular line will be made based on information they obtain via electronic monitoring of traffic volume and vehicle spacing, voice communication from drivers and engineers, and any alerts from safety and security teams.

In the aftermath of the dispatchers' decisions, the status information is then updated and may affect each of those worker positions on alternate lines of the network. There are few if any decisions made that have only isolated outcomes.

Robust transit systems analysis tools need to help dispatchers and others in the network to predict outcomes to altered scheduling, but such tools must also be streamlined sufficiently to simplify and shorten the dispatchers' choice-selection option list in a reasonable available time frame. When provided with data from such streamlined systems analysis, dispatchers can improve the effectiveness of their decision-making activity and thus help solve and reduce real and potential delays.

Such outcomes will tend to help maintain operational effectiveness in a range of other functions, such as employee safety, customer safety and ride assurance, rolling stock maintenance, overtime reduction, and exposure to internal or external insurance and legal claims.

In many cases, the trial period of a proposed new operational rule set requires that the transit system operator rapidly gain an understanding of the long-term usefulness of the rule set under actual conditions and diverse scenarios. By applying arrays of street, station, and intersection sensors and wireless telecommunications of data with database sorting and display tools appropriate to the trial, the operator could, for instance, more quickly and reliably gain confidence in results.

Developers of transit systems analysis software and interface hardware are aware of these advantages and are constantly seeking to provide improved internal code and external interface modes. A sensor-and-software system to determine shortest-route connections in a transit network is not a new idea, but the technology to deliver such a system is constantly evolving; each new version may present a transit operator the opportunity to pass its established cost-benefit threshold for installing such a system.

Reporting Requirements

In large public transportation bodies, there are many touchpoints with external constituencies and various government entities. Transit systems analysis can help keep communications with this plethora of partners up to date and effective.

The abilities of workers and manager to perform these communications duties are often challenged by (1) the amount and complexity of data needed to assemble accurate and comprehensive reports and (2) the number of corresponding agencies and the degree of variance in their information requirements.

For example, a single unit in the California Department of Transportation—the Office of Administration and Budgets of the Division of Mass Transportation (MassTrans)—is tasked with constant liaison with this range of state agencies:

- California Department of Finance
- California Department of General Services
- California State Personnel Board
- California Department of Personnel Administration
- California Division of Business, Facilities and Security
- California Division of Human Resources
- California Division of Labor Relations
- California Division of Procurement and Contracts

MassTrans is also tasked with liaison with Departments of Transportation in other states, and also with these and other federal and nongovernmental correspondents:

- U.S. Department of Transportation
- Federal Transit Administration
- Federal Highway Administration
- American Public Transit Association
- California Transit Association
- California Association for Coordinated Transportation
- Community Transportation Association of America
- National Rural Transit Assistance Program
- Multi-State Technical Assistance Program
- Local Technical Assistance Program

In its communications with these agencies, MassTrans must conduct information sharing on a range of priority areas, including intelligent transportation systems (ITS) requirements, planning grants, toll credits, and transportation development credits. Additionally, these communications must be made in such a manner as to accommodate at least two separate major constituent domains—the state and the federal—and the language must be tuned to the diverse programs administered within each domain.

Each of these correspondents, along with numerous others, can be an originator or channel of funding or technical support to MassTrans. Therefore, it is imperative that they each be provided with adequate and accurate data derived from performance metrics as acquired and measured by the transit systems analysis tools MassTrans has in place in its various operational modes and networks. As stated in its mission statement, the Transit Systems Analysis Branch (TSA) of MassTrans must generate data

related to the fiscal status and performance of public transit operators throughout California. The TSA Branch is responsible for the creation of a central data source which will provide management and staff the information necessary to respond to inquiries quickly and efficiently.

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See Also: Benefit–Cost Analysis of Transportation; Supply-Chain Management; Transit System Technology.

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Transit Tunnels, Design and Construction of

Transit tunnels are enclosed underground passageways constructed for use by transit systems and in many cases—as with subway systems—comprise either the bulk of the network or at least the central portions of it.

The design of a transit tunnel begins with a clear statement about what is needed—the points the tunnel needs to connect, and how many possible routes it may take—before the engineer is free to select the best choice from among multiple possibilities. Based on this defined goal, a geotechnical investigation of the site or potential sites begins.

Geotechnical investigation is undertaken by geologists and geotechnical engineers and reveals information about the soil and rock at a given site so that the correct and safe construction choices can be made. The process involves both surface and subsurface investigations. Surface investigations usually include geologic mapping, which produces a map showing geological information such as faults, folds, foliations, lineations, and exposed geologic strata.

Numerous high-resolution photographs are taken both for documentation purposes and for photogrammetry (the examination of photographs in order to learn about geological features); they can be shared with engineers who are not present at the site, which makes it easy to gather input from them. Thermal scans, high-resolution ultrasonic scans, and radar may be used for further investigation of the site.

Soil samples are taken using small-diameter borings, which allow for an examination of the

stratigraphy of the site. The standard preparation test can be performed on-site and provides information about local soil properties and grain size. Other tests pertain to the seismic conditions of the site, groundwater and groundwater pressure, and subsurface gas concentrations.

The flat plate dilatometer test measures the strain of the soil in response to varying levels of applied stress at different depths, which helps predict the effects of building the tunnel. Later, tests are performed in the laboratory to test the consistency of soil, soil content, the shear of the soil, water content, and other factors, as well as to confirm the results of on-site tests. Geophysical exploration during the investigation can help predict the response of the site to seismic events. This is relevant even in areas that are not known to be earthquake prone, not only because much of the country has the potential to experience an occasional earthquake, even if not

frequently, but also because seismic events that are not severe enough to cause significant disturbance aboveground can still have subsurface ramifications that are especially important to underground construction.

One of the main goals of the geotechnical investigation is to determine the stand-up time (the time the tunnel can support itself without other structural support) of the proposed tunnel, which bears on the plans and timetable for the excavation work. Stand-up time is affected not only by the soil conditions but also by the tunnel shape: the greater the ratio of height to width, the longer the stand-up time, all other things being equal.

Geotechnical investigations also devote a lot of time to studying the groundwater, which is key for tunnel construction to prevent erosion, freezing, and flooding. Hydrologists are usually consulted on groundwater matters. In some cases,



A view from the mezzanine at the University Street transit tunnel station, or Metro Bus Tunnel, in Seattle, Washington. The tunnel runs the length of downtown Seattle for 1.3 miles (2.1 km). Construction began on the tunnel in 1987 and was completed in 1990 at a total cost of \$455 million. In 2005, the tunnel was closed for a two-year project to modify the structure to accommodate light rail.

a site might be found unsuitable for tunnel construction, although usually this discovery is made early in the planning process during preliminary investigations.

Infiltration of groundwater into tunnel elements is the primary contributor to tunnel deterioration, both for older concrete tunnels and for modern tunnels. Groundwater also plays a role in the severity of deterioration induced by freeze–thaw cycles over time. Depending on where the tunnel is being dug, other man-made infrastructure may require relocation, such as electrical cables, pneumatic tubes, and water and sewer pipes. Foundations of buildings or abandoned older construction may also be in the way. In Europe, a frequent obstacle in the construction of subway tunnels is the subterranean ruins of older cities.

Once the tunnel site has been chosen, there are different methods of tunnel construction that are suitable to different conditions. The two principal methods of tunneling for subway systems are cut-and-cover and deep-bore. Cut and cover is the older method of subway tunnel construction and consists of essentially digging a trench and covering it; the surface is removed and the subsurface is excavated, after which the surface layer is put back in place. Subway tunnels dug in this way generally followed the street layout and created subway stations fairly near to the surface.

Cities with older subway systems, originally, at least, had tunnels created with the cut-and-cover method (although not by the machines that would be used for the work today). The method continues to be used because it remains the cheapest, but it often inspires community complaints because of the effect on traffic and the noise in the neighborhood during the construction process.

When Vancouver, British Columbia, used the cut-and-cover method to build its Canada Line in the 2000s, dozens of lawsuits were filed due to the disruption to local businesses. While the largest initially successful lawsuit was overturned on appeal, it still sent a warning signal to other metropolitan areas considering cut-and-cover.

The more recent deep-bore method begins with a hole dug somewhere along the proposed tunnel route into which a boring machine is inserted. Once running, a boring machine excavates a circular tunnel at a rate of up to 80 feet per day. Tunnel borers are transported piece by piece to the site,

due to their size and weight, and consist of scrapers and discs that crush rock and debris in front of the machine. A conveyor transports the crushed remains to the machine's wake, where a tunneling crew collects and disposes of them.

Unlike cut-and-cover tunneling, deep-bore tunneling does not interfere with surface activity, except at the point where the boring machine enters. Streets and other structures function safely and normally while the boring machine is excavating below. Deep-bore tunnels are located farther beneath the surface than cut-and-cover tunnels and are much more expensive. However, much of that cost is the initial capital investment, and that can be somewhat absorbed if an extensive tunnel system is planned.

This is especially the case if the goal is to create a basic system at first and then continue to expand it over time, keeping the expensive boring machine in use and thus continuing to extract value from it. Deep-bore construction is not possible in all areas. The groundwater does not always permit tunnel construction far below the surface, or soil conditions may not be amenable. Deep-bore construction also requires deeper stations and, in practice, deep-bore routes are usually assigned fewer stations, which dictates a different sort of route map.

Transit tunnels are generally touted as benefiting local business, but the increased traffic that brings those economic benefits can also bring significant noise and air pollution. Tunnel construction is often an area of concern, as its effects may be felt farther from the site than originally projected, and it may be disruptive to local construction (including historic buildings), local businesses, residents, and ecosystems. Disasters also cast a negative pall on such tunnels, and past problems may be brought up when new plans are considered. For instance, in 1995 the collapse of a portion of tunnel in the Los Angeles subway led to a sinkhole that consumed an 80-foot-wide area of Hollywood Boulevard. Flaws were later found in the tunnel's design.

One of the most famous transit tunnels is the Channel Tunnel or "Chunnel," which runs beneath the English Channel, the body of water separating England from the European mainland. At 31.4 miles of undersea rail—the longest undersea rail in the world—it connects Folkestone, Kent, in the United Kingdom, with Coquelles, Pas de Calais, in France.

The Chunnel transports passenger trains (the Eurostar service), freight trains, and the Eurotunnel Shuttle. The Eurotunnel Shuttle is a roll-on/roll-off vehicle transport, providing a service analogous to that of a ferry. This allows private citizens to travel back and forth between England and France in their own vehicles, which is a considerable boon to tourism for both regions, making trips easier and more affordable and encouraging casual and impromptu recreational trips.

Projects like the Chunnel had been discussed for decades but always stalled until 1986, when the Eurotunnel company was founded for the purpose of building the tunnel. Construction began two years later, and the Chunnel opened in 1994. The forecast levels of freight and passenger traffic both proved to be overestimations. Passenger traffic (including both the Eurotunnel shuttles and Eurostar's passenger service) peaked at 18.4 million people in 1998, and neared that peak in 2012, with 18.2 million.

Although the 1998 figure consisted mostly of Eurotunnel shuttle passengers (about 12 million), Eurotunnel usage has declined and Eurostar usage has gradually risen. On the other hand, Eurotunnel shuttle usage has increased significantly for freight trucks, while freight train tonnage has decreased steadily since 1998. The Chunnel has also attracted attention because of the attempts of immigrants and refugees to use the tunnel (stowing away on freight trains in most cases) to enter the United Kingdom.

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See Also: Highway Tunnels; Subway Systems; Tunnels, Safety and Security Issues in.

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Transit Vehicle Capacities, Loading Criteria and

Although transit vehicles include a wide variety of modes and can range from ferryboats to rickshaws and from taxicabs to pedicabs, the science—and math—of determining the capacity of public transit vehicles and loading criteria most often involves shared passenger transportation services in urban centers. This most often includes buses, subways, and trains and rapid transit systems, under the supervision of a centralized transit authority responsible for ensuring both efficient and safe service. The data is staggering—each year in the United States alone, more than 10 billion passengers avail themselves of public transit systems. On any given day, 35 million people board public transportation; the usage of public transportation in the last decade has spiked more than 35 percent. The volume of traffic using public transit has compelled the determination of capacity and loading criteria to become a science.

The factors that go into determining the capacity of these transit vehicles must take into account not merely seat numbers, aisle width, and seat width but also the capacity of the conveyance to permit standing passengers; then it must factor in what constitutes not only a safe range of capacity but also a bearable ride. Because public transit systems are public services and rely on the business of their passengers (after all, tickets provide the largest share of revenue), capacity determinations must be guided by the pragmatic matters of providing a safe and a comfortable ride for both seated and standing passengers.

In addition, metropolitan transit systems interested in expanding or cutting back on services and lines of transport use transit vehicle capacity determinations as part of the equation in any assessment of current services. Transit vehicle capacity and loading criteria are often critical factors in determining when—and if—public transit services need to be expanded or cut back.

What, urban planners and metropolitan transportation boards ask, constitutes a crowded bus or a packed subway? When the transit vehicle is at peak operation, the critical determinant in vehicle capacity calculations, what volume of passengers

qualifies as a crowd? The math is both precise and intricate.

The International Association of Public Transport has defined load factor as how crowded a bus or subway train has to be in order to justify additional services. In the formula for measuring capacity, load factor is most often represented as the number 1 expanded to two decimal points to represent the percentage of filled seats. For example, when a bus is full, the load factor is said to be 1.00, and there are no empty seats. If the load factor is moved to, say, 1.25, this means that not only is the bus full but 25 percent of its capacity is standing. If the load factor is moved to 1.50, this means that not only is the bus full but in addition, 50 percent of its capacity is standing.

Comfort becomes a problem. How many passengers can fit into a public transportation vehicle? The average tolerable load factor for most city buses, for instance, is 1.25. More than that and comfort and safety are compromised.

Bus Capacity Calculations

The math for bus capacity is impacted significantly by whether the bus is an old-school high-floor bus or a relatively recent low-floor bus. Although both are relatively the same dimension, about 45 feet long and 9 feet wide, the internal design is significantly different and creates far different capacities. In the high-floor bus, passengers must step up to gain entrance to the seat aisle, most often four steps from the street to the floor of the bus, past the driver and the fare meter.

The elevated high-floor design traditionally provided passengers with an impressive perch for viewing the passing scenery; these buses could seat somewhere between 60 and 70 passengers: 45 seated, and the rest standees. But the four steps proved an obstacle for passengers, not only those with physical impairments (indeed, the buses were eventually retrofitted with wheelchair lifts, but they take significant time to engage). The design further tended to clot people in the doorway as passengers negotiated the steep steps in all sorts of weather while trying to pay the fare for the ride and thus slowing down transit service.

In newer bus models, low floors were introduced, allowing passengers to simply step from the street onto the bus. These floors were introduced in the 1990s to make bus riding more accessible for older passengers and special-needs riders. Seating

capacity was in turn impacted—there are fewer seats, on average 38, which makes a low-floor bus capacity closer to 55. However, loading and unloading is made more efficient, as has the use of pre-paid computerized bus fares and PayPal accounts. Because of the low floor and because in high-floor buses standing passengers can line the aisle all the way back, a low-floor bus, although it holds fewer passengers, can actually feel far more crowded, thus impacting determinations of passenger capacity.

In express buses, the load capacity is further impacted by the speed of the buses—in such few-stop routes, the load factor has to be maintained at 1.0, that is, all seats taken but no one standing, as the speeds and stops might be a problem.

High-Capacity Transit

By contrast, high-capacity transit trains move significantly more people at a significantly faster pace than buses. However, train systems operate under similar constraints when determining the vehicle capacity for either a subway car or a high-speed transit line train. Because train car dimensions can vary, vehicle capacity can vary.

In New York City, for instance, the average subway train is 8 to 11 cars long (each roughly 75 feet long, although some are far shorter—closer to 50 feet—depending on the line of service). Thus, it is difficult to determine what the vehicle capacity is for a subway train. The number for vehicle capacity can range from 110 to 175 passengers.

The city's transit authority has measured what it deems an acceptable personal space for strap-holders, that is, the circumference space the average-sized standee (and weight and height variables are factored into the capacity numbers) should expect for both comfort and security at peak riding hours.

Although a generation ago the number was put at 4 square feet around each standee, the number has been significantly crunched to 3 square feet to maintain an efficient and economic subway system. Generally, then, an average subway train of 10 cars with an average loading capacity of 100 passengers per train vehicle can transport 1,000 passengers per hour at peak time.

Over the last 10 years, however, vehicle capacities in subway trains in major cities, particularly in Europe, have been significantly enhanced by the introduction of articulated cars (i.e., subway cars without the traditional cumbersome apparatus of

hydraulic doors between individual cars). Rather, the lines of cars are linked by accordion-like bridges that create an unbroken interior space.

The longer subway car design not only provided a safer ride, as passengers were less likely to be sequestered and apart and hence vulnerable to criminal elements, but significantly improved loading and unloading times. Articulated cars further eased the claustrophobic sense of isolation inherent in the older designs as passengers were freer to move about the entire train. Vehicle capacity increased by as much as 10 percent with the additional interior space. Any model for public transportation systems now recognizes both the physical limitations of public transit vehicles as well as the human factor, that is, the space required by the passengers themselves to provide both a safe and comfortable conveyance.

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See Also: Bus Rapid Transit; Transit Industry, Economics of; Transit Systems; Transitways.

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Transit-Oriented Development

Transit-oriented development (TOD) refers to pedestrian-friendly, high-density areas in close proximity to a public transportation system. Following the principles of smart growth, TOD zones have planned residential and commercial mixed-use development situated within walking distance from a fixed-route public transit station. TOD

projects are expected to foster economic development by boosting property values and mitigate the negative environmental impacts of transportation by reducing automobile usage by local residents.

Developers and urban planners work to create a comprehensive and integrated land use plan that encourages smart growth and new urbanism design principles for TOD projects. These principles include easy transit access, pedestrian friendly site design, residential and commercial mixed-use development, and variety of housing options and housing costs. The first goal of TOD is easy transportation access, allowing residents to live close to public transportation options. These residents can commute to work by walking or biking from their home to a transit station.

The most successful TOD designs concentrate development within two zones of the transit station: an initial quarter-mile zone and a secondary half-mile radius around a transit station. Planners consider the quarter-mile and half-mile zones around TOD development to be the distance an average commuter would walk to and from a transit station. Extending a TOD zone requires increased connectivity, such as regular and frequent bus services radiating from the transit station to facilitate a more interconnected transport system.

The second goal of TOD is spurring economic growth, as development projects reshape the topography of urban property values and embed spatial arrangements that establish new clusters of economic growth. The design of transportation infrastructure is thought to create areas of economic growth that can work with local efforts to create a more competitive regional economy. Long-term investment in alternative transportation infrastructure is an attempt to establish pockets of concentrated economic growth.

Embedded in these economic development initiatives are assumptions about the need to establish a "creative city" through amenity growth, resulting in a TOD designed to attract an expanded ridership of young, creative professionals. According to the creative cities thesis, transit systems meet many of the perceived prerequisites for creative growth by establishing transportation amenities and TOD zones around rail stations to attract capital investment and foster economic development.

The third goal is to reduce the environmental impacts associated with automobile transportation

and mitigate the need to expand infrastructure to meet the needs of urban sprawl. By reducing the number of automobiles on the road during commuting hours, cities can reduce their greenhouse gas emissions. This becomes very important for urban areas that are designated nonattainment zones, which indicates the area has exceeded the Environmental Protection Agency's (EPA) threshold for air pollution. Encouraging public transit use and pedestrian commuting also reduces the need for expanding road capacity. By reducing the need to add more paved highway lanes, there are fewer impervious surfaces that generate polluted storm-water runoff and impact overall water quality.

TOD has become a key feature for rail transit projects. Rail transit, much like TOD projects, is conceptualized as a tool for managing urban sprawl, stimulating economic growth, and reducing environmental impacts, because transit systems establish dense urban corridors for future development projects. The subsequent TOD provides opportunities for cities to reshape their urban form and stimulate capital investment. By establishing dense mixed-use TOD projects adjacent to light rail, commuter rail, and metro stations, planners hope to foster the establishment of livable, economically prosperous, and environmentally sustainable communities.

Light rail and commuter rail stations are designated as either feeder stations or destination stations, which result in different manifestations of TOD projects. Feeder station areas are more residential suburban areas that often have TOD projects that include neighborhood restaurants, dry cleaners, and grocery stores. These feeder stations are usually less dense and have park-and-ride lots.

Destination stations are usually located at the central business district, government centers, or near entertainment venues. These areas have high-density TOD designs that can include mixed-use housing, office complexes, stadiums/arenas, and other entertainment centers. Often TOD projects around destination stations do not have park-and-ride lots and are in areas with few parking spaces. In an effort to reduce automobile congestion and create more space for commercial and residential development projects, many cities modify zoning codes to reduce the required number of parking spaces in areas adjacent to TOD projects.

To make transit-oriented districts around urban rail transit successful, these areas must have

adequate bus connectivity and a pedestrian-bike-friendly infrastructure. Bus connectivity allows for residents to reach feeder-station development zones and allows riders to disperse from destination stations downtown.

To facilitate this expansion, frequent circulator buses must connect with the rail station and quickly move passengers beyond the quarter-mile inner circle and the half-mile outer circle of TOD walkability. To accommodate bike and pedestrian traffic, TOD zones should widen sidewalks, establish bike lanes, and provide safe, well-lit spaces for night travel. Some development areas have bike-share or bike-rental programs that allow commuters to have bike access once they get to their destination.

Some critiques of TOD point to the potential of increased property values to displace low-income residents in the area. These potentially negative impacts of so-called "transit-oriented gentrification" can be addressed by ensuring enough affordable housing options in the TOD zone. Like other smart growth and new urbanism projects, TOD projects should work to ensure a healthy mix of income levels and socioeconomic diversity.

Having affordable housing within a TOD zone can be a way to reduce the number of residents who will be displaced by rising property values. It also serves to make TOD more effective by allowing service-sector employees in TOD neighborhoods to afford to live in the neighborhood. That allows residents to live in the area where they work and encourages the pedestrian and transit usage that makes TOD zones more successful.

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See Also: Integrated Transportation and Urban Land Use Planning Models; Neotraditional Neighborhoods and Transportation Impacts; Pedestrian-Friendly Design; Smart Growth; Transit Centers; Transportation Impacts on Land Use; Urban Sprawl Versus Compact Development.

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Transitways

As metropolitan areas throughout the nation grapple with mounting concerns over traffic congestion, poor air quality, and fossil-fuel dependence, policy makers often turn to public transportation for solutions. Particularly within the context of fiscal limitations, the "transitway" concept is seen as an attractive and cost-effective strategy for improving transit efficiency and alleviating congestion in major travel corridors.

In general, a transitway is an exclusive, limited-access roadway or a travel lane or lanes of a roadway—also called a dedicated right-of-way (ROW)—reserved for public transit. The transitway includes associated infrastructure, such as stations, transit terminals, and park-and-ride lots. Transitways may also be referred to as busways, bus/carpool lanes, high-occupancy-vehicle (HOV) lanes, or commuter lanes, or transit lanes, T2 lanes, or T3 lanes in Australia. Transitways are most frequently associated with buses and trolleys.

Bus rapid transit (BRT) systems often use transitways for the long-haul portion of travel. In some situations, emergency vehicles, taxis, and high occupancy vehicles such as carpools and vans may be authorized to use transitway facilities.

Transitways are a special category of roadway designed to provide faster operating speeds, better trip-time reliability, and an overall higher level of transit service than what is typically provided on arterial streets. When properly implemented, transitways have the potential to maximize the person-moving versus the vehicle-moving capacity of the roadway. This article defines transitways, describes their overall characteristics, and provides an overview of benefits and drawbacks.

The term *transitway* appears to have originated in the Ottawa region of Ontario, Canada, where Ottawa-Carleton Regional Transit Commission (OC Transpo) launched its "Transitway" in 1983. One of the most extensive and successful transitway implementations in North America, OC Transpo's Transitway serves as the backbone of the rapid transit system for the Canadian capital area.

Transitway facilities have been implemented in locations throughout North America, including Pittsburgh, Pennsylvania; Washington, D.C.; the Lincoln Tunnel between New Jersey and New York City; Los Angeles and San Francisco, California; Boston, Massachusetts; Miami, Florida; Houston, Texas; Seattle, Washington; Cleveland, Ohio; and Eugene, Oregon. Transitways can also be found in Bogotá, Colombia, and in Brisbane and Adelaide, Australia.

Transitways in the United States are typically implemented by a state department of transportation (DOT), and can assume a variety of configurations and operating arrangements, from simple provisional lanes to fully grade-separated facilities. Physically segregated transitways include at-grade or grade-separated roadways or lanes developed within a separate ROW, barrier- or buffer-separated roadways developed within the freeway ROW, exclusive facilities developed in the median of an urban street, and arterial bus streets and bus tunnels.

In some situations, freeway, arterial, or shoulder lanes that are not physically separated from other traffic lanes function as transitways. These lanes may be concurrent flow lanes, which are lanes in the peak direction of traffic flow, or contra-flow lanes, which are lanes taken from the nonpeak direction to provide additional lanes for the peak-flow direction.

Transitways may provide further time savings by means of additional transit priority measures, such as bus signal priority and queue jumps. Signal priority for traffic lights uses specialized signal phasing to provide extra time for buses to move through intersections. Queue jumps allow buses to bypass traffic backups at ramp meters, toll plazas, and intersections. Different types of transitway facilities vary in the travel time savings they provide and therefore have different levels of effectiveness.

Benefits

By allowing travelers to avoid congestion on high-demand urban corridors, transitways can offer significant travel time savings compared to adjacent

freeway lanes. In addition to providing faster average operating speeds for vehicles, transitways generally enable higher frequency service, resulting in reduced out-of-vehicle waiting times, and increased corridor carrying capacity relative to regular local bus service. Also, while traffic congestion, accidents, breakdowns, and weather contribute to greater travel time variability on freeways, transitway users experience more predictable travel times.

These benefits provide an improved overall passenger experience in comparison with conventional bus service and may produce increased transit and carpool/vanpool use. This in turn may ultimately lead to increased person volumes without the corresponding increases in vehicle trips and vehicle-miles traveled (VMT) that usually occur with the addition of traditional highway capacity. During the peak hours, for instance, a transitway lane can carry up to three times more people than an adjacent freeway lane. In short, well-designed and appropriately situated transitways can save energy, decrease emissions, and reduce the need for new highway construction.

Transitways can also offer savings in overall system costs and implementation time. Costs vary greatly by type of facility, from \$1 million to \$30 million per lane-mile. Cost comparisons naturally reflect local conditions such as traffic patterns; terrain; the need to obtain right of way; the degree of segregation, if any, from general-purpose lanes; necessary pavement treatments; and the design and operational features of various transit alternatives (for example, standard buses versus high-capacity articulated vehicles). Nonetheless, transitways have been found in most cases to require less capital investment than other capacity improvements, such as highway or rail development.

Factors that have been shown to significantly affect expenditures for transitway facilities include the costs of ROW acquisition or land, overhead walkways for passenger safety at stations, additional passing lanes at stations to accommodate large numbers of buses, and modifications to bridges, overpasses, ramps, and interchanges. Fully grade-separated transitways have the highest capital costs of all transitway types, but also provide the highest travel time savings, reliability, level of safety, and peak passenger capacity.

Another advantage of transitways is their inherent flexibility in meeting the needs of unique local

contexts, including travel demand patterns, safety concerns, enforcement requirements, and available resources. For example, buses can adapt if a roadway is closed or destinations change, and several bus routes can converge on one transitway. This provides the flexibility to tailor service to demand without increasing the need for passenger transfers, which have been shown to be a major factor in discouraging transit ridership. An additional benefit is that transitway implementation may proceed incrementally, with small, independent segments or technologies that become operational as funding becomes available and construction is completed.

Challenges

Many transitways include permanent stations, which provide opportunity for development intensification and diversification along the corridor and around stations. However, transitway stations are typically large and can be difficult to integrate into pedestrian-friendly areas. Because easy pedestrian access to stations has an impact on land development and overall transitway success, the importance of pedestrian-oriented station design is paramount.

Another important consideration is that specialized stations require increased capital outlays, and appropriate ROW may be difficult or expensive to obtain. As an example, multiple lanes may be necessary to allow passing at stations where boarding volumes are high or local and express services are operated concurrently. Studies have shown that transitways, particularly those without grade separation, must be strictly enforced in order to be effective. Without enforcement, interference by unauthorized vehicles such as automobiles, taxis, and trucks can significantly diminish transitway performance and safety, especially when general-purpose vehicles must occupy bus-only lanes to make right turns.

Due to the significant amount of traffic control officers required for enforcement, alternative approaches such as left-side bus lanes combined with boarding islands have been used to increase the effectiveness of transitways. Contra-flow lanes have sometimes been introduced as another strategy to prevent vehicles from entering transitway lanes. The drawback to this option is that it creates a safety hazard for pedestrians who may not anticipate a vehicle coming from the opposite direction.

To keep general-purpose traffic out of the transitway and encourage pedestrian safety, appropriate demarcation such as pavement coloring and roadside/pavement signs should be used, especially at merge points and intersection crossings. In addition, the complexity of transitway operations and the ROW limitations that accompany many applications underscore the need to consider traffic operations management strategies, including surveillance, communications, and control capabilities, early in the planning and design phases.

Other Issues

Other relevant issues that must be considered when implementing a transitway include the compatibility of large numbers of line-haul buses on neighborhood streets; the treatment of disruptions in central business district segments (such as the elimination of parallel parking and restrictions on turning movements by general-purpose traffic) for integration of the transitway with the urban setting; and the affect of environmental factors, such as noise and air pollution, on the activities of the central area.

Transitways are most effective when implemented as regional networks with a system of supporting facilities and services. For example, grade-separated systems such as Ottawa's Transitway, Miami's South Busway, Pittsburgh's transitways, and Bogotá's Transmilenio are operated with integrated networks, including routes that serve all stops and a variety of feeders and express services with integrated off-line and line-haul operation. There are also indications that long-term impacts of transitways may be greater than short-term impacts, reflecting the synergistic effects of various program elements and the influence of marketing and promotional campaigns.

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See Also: Bikeways/Bike Lanes, Road Design Issues of; Bus Rapid Transit; Busways and Reversible Bus Lanes; Commuter Buses; High Occupancy Vehicle Lanes; Streetcars/Trolleys; Traffic Signal Priority; Transit Priority Measures.

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Transportation, Economics of

Transportation economics is a broad field. It is an established branch of neoclassical economics, while also having connections to the theories of the provision of public goods, land use planning, and public-sector financing. Transportation is the means for the movement of people and goods across space, be it across land or water or through the atmosphere. This unique function inserted transportation as an integral part of regional, national, and international economies since the first days of commercial transactions.

Transport does two basic things for an economy. First, it enables the assembly of material resources and of labor at the sites of production. Transportation is thus pivotal to the successful operation of the supply chains that underpin any economy. Second, transportation enables the dispatch of products to markets. Efficient transportation links to distant potential markets enable a producer to expand output and so enjoy the benefits of economies of scale and divisions of labor.

A way to understand the importance of transportation to the economy is through the notions of efficiency. There are three types of economic efficiency. One is "allocative" efficiency, which is the extent to which resources are allocated to different types of producers in ways that maximize consumer satisfaction over the full range of available goods and services.

Transport plays a crucial role in moving factors of production and final products, sometimes over



Semitrailer trucks may move materials and final products over vast distances in order to sustain economic activity. These trucks were forced to travel through this mountain pass in 2011 in order to bring goods from Pakistan to Kabul, Afghanistan.

vast distances, in order to enable each producer to operate at a level that ensures the best product is made at the lowest possible price.

Another is distributive efficiency. This refers to the extent to which an economy supplies goods and services to those who need them most. Here, the efficiency of transport systems not only enables producers to operate at the necessary production levels but also, importantly, to make final products accessible to disparate groups.

Finally, there is dynamic efficiency, which refers to the capacity of an economy to abandon the production of those goods and services where demand levels are falling in favor of those economic products growing in popularity. Transport plays a major role in both creating awareness of new products and enabling producers to gain access to new sources of supply and to reach new markets.

Of course, transportation systems move people and things for reasons other than for the supply of labor and production materials and the delivery of goods to markets. People also move around

for family, social, and recreational reasons, as do goods. Voters insist, then, that transportation systems be made available to serve a wide variety of objectives, not simply economic ones.

This multipurpose demand on transportation systems creates complex operating environments for different transportation modes. Inevitably, governments and planners must compromise on which transportation systems are possible in the face of extensive demand and limited financial resources.

Role in Overall Economy

Studies of the aggregate impact of transportation on the economy identify two major influences. One is the direct economic effects of the transport sector itself. The value of the transportation sector in advanced economies ranges between about 3 percent and 5 percent of gross domestic product. Another effect is the value that is created by transportation across all sectors of the economy, and here transportation's contribution to gross domestic product is estimated to be around 15 percent to 20 percent.

Positive and Negative Externalities

In addition to the direct benefits of transportation to producers and consumers, transportation creates positive externalities for the economy. This happens in two ways. First, transportation enables the assembly of critical masses of people and, second, it establishes the physical possibilities for these people to enjoy the benefits of being in urban concentrations. These benefits include rising prosperity that comes from expanding levels of production in expanding markets, and the jobs and incomes that are generated.

Yet, providing transport services to concentrations of people in urban areas and their agglomerations of economic activity will necessarily generate undesirable outcomes. Oversubscribed or malfunctioning transport systems mean congestion, rising inefficiency, and higher costs. Negative externalities can also involve unwelcome noise, poor air quality, and unsightly outlooks. While these are not directly paid for any individual producer or consumer, they will affect the cost structures and revenue opportunities of a city's economy into the future because its reputation as a desirable place to invest, live, and work is diminished.

Cost Structures

An important aspect of transport economics involves the analysis of the costs of transport and the ways various costs structures affect transport modes and operation. Every transport mode is differently composed according to the target user group.

A fleet of taxicabs, for instance, is designed to move people on their own or in small groups across short distances in flexible ways. On the other hand, a giant oceangoing ore carrier is designed to move the commodity in large quantities over long repeated distances. Therefore, cars, buses, trains, aircraft, ferries, ships, and so on have different entry costs and different operating costs according to variables such as initial capital outlay, relative fuel efficiency, speed, payload, loading and landing costs, labor costs, and regulatory costs.

In general, large loads carried over long distances involve capital-intensive equipment, but lower variable costs. On the other hand, smaller payloads, for example, 50 people in a metropolitan commuter bus, will incur higher fuel and labor costs but relatively lower capital costs. A major effect of distinctive cost structures across different transportation modes according to distance traveled is to make road travel more competitive over short distances, train travel over moderate distances, and shipping over very long distances.

Land Use Effects

The amenities of residential neighborhoods and the productive efficiencies of commercial and industrial areas are greatly enhanced by the quality of transportation systems that service them. Key here is not just the range and frequency of transportation services but also the extent to which these services are sequenced and synchronized to match the needs of transportation users.

A residential neighborhood, for example, benefits from reliable frequent commuting services during morning and evening peak periods. An industrial area, on the other hand, might need regular servicing 24 hours a day by heavy vehicles and rail services. A consequence of quality transportation services is to raise the value of land in well-served areas. Historically, concentrations of transport services are found in and around urban centers, especially central business districts (CBDs). Frequent passenger transportation services, for example, supply a CBD with workers in the early hours of

the day, and then business clients and shoppers throughout the day.

Access to labor supplies, clients, and customers then makes a CBD a prime location to do business. As a direct consequence, property developers are anxious to erect multistory office towers and elaborate shopping centers, fueling the high demand for office and retailing space in such a CBD. Similarly, the quality of available transportation services significantly affects the land prices in residential and industrial areas and has a major impact on the long-term growth prospects of regional and satellite urban centers.

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See Also: Economic Development; Freight Transport, Intermodal and Multimodal; Privatization of Public Transit; Transportation Impacts on Land Use; Travel Demand.

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Transportation and the Disadvantaged

There are two ways in which people who are disadvantaged to some extent—including those who live in poverty, the elderly, people with disabilities, people in minority groups, and women in general—might be considered in the context of transportation studies. The first concerns the transport habits and access to transit of socially disadvantaged groups, and the second concerns how transportation systems (or a lack of transportation) might be responsible for producing and reinforcing disadvantages.

A focus on the “transport disadvantaged” or “mobility deprived” is broadly defined as an inability to get to where one needs to go (for work, school, medical care, etc.) without experiencing difficulty or restriction.

Restriction may result from geographical exclusion, economic exclusion, fear-based exclusion, or lack of physical or mental ability. Studies concerned with the disadvantaged in matters of transportation have made links between transport disadvantage and unemployment, urban deprivation, health care inequality, and underachievement in education.

In making a distinction between social disadvantage and transport disadvantage, it is important to note that the two do not always go together. For instance, it is possible to be socially disadvantaged but have good access to transport, or to be socially advantaged but have poor access to transport. Equally, restricted access to transport does not always equate to transport disadvantage if travel is not a requirement for daily living.

One school of thought views travel problems of disadvantaged groups as an issue that can be adequately addressed through the increased provision of public transport. However, recent studies have argued that access to an automobile is more important than access to public transit in this day and age. This is especially the case with lower-income people who may be dependent upon transportation for employment opportunities.

Lower Income Groups and Welfare Recipients

It is often the case that many disadvantaged groups also fall into the category of lower income. Lower-income groups are likely to be geographically disadvantaged and reside in areas with poor access to transport services. Where access is provided, lower-income people might be priced out of some forms of public transport because they cannot afford it. For example, rapid transport systems (for example, bus rapid transit, light rail, and heavy rail transit) have been viewed as catering primarily for wealthier populations, and, indeed, higher-income people are more likely to use those modes while lower-income people are more likely to use buses.

Because more affluent people are more likely to own cars, they are unlikely to switch to public transit unless the advantages outweigh the convenience of their private vehicles, and these features include the ability to get to and move around cities more

easily and at quicker speeds. A low income is also likely to prevent those groups from accessing private transport, not only private cars, but also taxis and shared-ride services.

Transportation disadvantage is particularly problematic when public transport is not sufficient to fully accommodate the travel needs of the local population. For example, in cities such as Los Angeles, the population is largely dependent upon automobiles for daily mobility, access to services, and access to employment.

In the decades since mass private car ownership has allowed businesses as well as residents to locate to the suburbs, spatial distance often stands between low-income job opportunities (for example, in fast food and retail chains) and low-income residences. Even with access to public transport, commutes from the inner city to the suburbs may be counter to the general flow of commuters from the suburbs to the central business district, leading to slower, less reliable, and more inflexible transportation options, which again negatively affect the employment opportunities of lower-income groups.

The bus is commonly associated with lower income populations. When compared to the autonomy and speed of the automobile, or to the speed and relative comfort of rapid transit, buses are considered to be slower, less secure, less reliable, and less comfortable. In Los Angeles, lower-income groups that are affected by transport disadvantage are more likely to be newly arrived immigrants and ethnic minorities.

Women

Although it is impossible to generalize about the half of the population that is female, there are a number of factors that are likely to lead to the experience of transport disadvantage for women. Women are more likely to have a lower income than men, and are more likely to be responsible for child-care, care of the elderly and people with disabilities, and domestic duties, in general. The need to juggle these responsibilities can have implications for the geographical range that women are able to travel for work, often forcing women to take jobs close to their place of residence, regardless of their skill set and earning capabilities.

Studies have also found that women, like the elderly, are more likely than men to fear for their safety or feel vulnerable on public transport,



Bus commuters on an older-model bus in Lima, Peru, in 2009. When compared to automobiles or to the speed and relative comfort of rapid transit, buses are considered to be slower, less secure, less reliable, and less comfortable. In many places, lower-income people may be priced out of rapid transport systems such as bus rapid transit, light rail, and heavy rail transit. Higher-income people may be more likely to use those modes, while lower-income people are more likely to use buses.

limiting their mobility and the times at which they are willing to travel.

Finally, it is increasingly recognized that the physical differences between women and men should be considered more fully within transport studies, design, and policy. The differences in height, for instance, can make it difficult for women to use overhead racks on trains, while the use of public transport can be difficult when there are limited staff available to help women on and off transport with large or heavy items.

The Elderly

Elderly people are more dependent on public transit than other groups and are often provided with free or highly discounted access. In London, the Freedom Pass allows individuals over the age of 65 to travel for free on a wide network of public transit services. This free access is considered to improve the well-being of the elderly, who are not only dependent on public transport for access to health care and other core services, but for social

networking and other forms of community participation.

Elderly people are also more likely to experience physical difficulties and decreased personal mobility, with slowed reactions and a deterioration of eyesight and hearing. Access to public transport can be physically challenging (for example, no available seats, long and/or numerous flights of stairs, pushing and shoving on crowded vehicles during certain hours, etc.). While most transit systems have elevators to help passengers navigate multiple levels, those services may be difficult to find, dirty, or perceived as dangerous. Similarly, while most public transport systems have designated priority seating for the elderly or disabled, other passengers may or may not honor the priority-seating signage on crowded vehicles.

In addition, fear of large crowds, of falling, or of experiencing difficulties getting on and off vehicles often leads elderly people to avoid public transport.

Paratransit services (such as Dial-A-Ride in the United States or Ring and Ride in the United

Kingdom) are one solution, therefore, for providing door-to-door service for people who find it difficult to use public transport, including the elderly.

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See Also: Dial-A-Ride; Elderly and Disabled Travelers; Jobs–Housing Balance/Spatial Mismatch; Social Equity and Discrimination in Transportation; Spatial Equity Analysis; Women’s Issues/Gender Issues.

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Transportation Control Measures

Transportation control measures (TCMs) are a broad class of activities intended to improve air quality by reducing emissions from vehicles used for transportation and to reduce fuel use by encouraging energy-efficient means of transportation. Examples of TCMs include improving public transit and pedestrian and bicycle facilities so that those means of transport replace some automobile traffic, encouraging employers to offer flexible schedules so fewer people are on the road at peak traffic hours, and fostering the creation and use of shared-ride services so that fewer single-occupant motor vehicles are on the road, particularly during peak hours. In the United States, a number of TCMs are specified in the Clean Air Act, and TCMs

receive highest priority for funding under the Congestion Mitigation and Air Quality Improvement (CMAQ) Program.

Background

Transportation accounts for 33 percent of carbon dioxide (CO₂) emissions and produces numerous other toxic pollutants that are dangerous to human health. TCMs are activities that attempt to change aspects of present transportation practices to reduce these harmful effects.

Section 108 of the Clean Air Act, as amended in 1990, lists 26 activities that qualify as transportation control measures, including improved public transit, creation of high occupancy vehicle (HOV) lanes, improving access for pedestrians and cyclists, creating measures to curb extended vehicle idling, and creating programs to encourage voluntary removal of pre-1980 vehicles from the roads and the marketplace.

Specific programs can also qualify as TCMs if they are committed to in State Implementation Plans (SIPs) or will reduce transportation-related emissions by fostering improvements in traffic flow or reductions in vehicle use.

The Intermodal Surface Transportation Efficiency Act (ISTEA), passed in 1991, funds transportation projects and programs intended to assist regions in meeting ambient air quality standards. The CMAQ Improvement Program was established under ISTEA, and CMAQ is apportioned to states that then allocate funds within the state.

CMAQ projects are intended to produce measurable reductions in dangerous emissions products, including particulate matter (PM), nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOCs). However, for purposes of evaluating the effects of a TCM program, results can be described in terms of changes in travel patterns (for example, reduced person-trips or time of day of travel), reductions in vehicle activity (for example, total vehicle trips or total vehicle miles of travel), changes in traffic flow characteristics (for example, travel speeds), and changes in vehicle activity and traffic flow resulting in changes in emissions.

Public Transportation

One major class of TCMs involves encouraging the use of public transportation by providing available, affordable, convenient, and reliable services, and

using public information campaigns to make the population aware of the services available and the benefits of using public transportation. Examples of programs to encourage transit use include the creation of dedicated bus lanes to speed travel, park-and-ride facilities, and discount-fare or other incentive programs, as well as upgrading transit vehicles and shelters. The use of public transportation reduces emissions and fuel use, while also reducing congestion and improving traffic flow. Transit may also provide a better experience to the rider. For example, it is possible to read while riding the bus or train, and it is not necessary to pay attention to the road.

Transit-oriented development (TOD) encourages both the use of public transportation and the development of neighborhood-scale developments that can be traversed on foot. The concept behind TOD is to encourage development of mixed-use centers near transit stations; such developments may include housing and a variety of commercial entities, including shops, restaurants, and entertainment sites such as movie theaters and nightclubs near transit stations.

People who live in such areas can meet many of their daily needs (for example, grocery shopping) on foot, while using public transportation if they need to make a longer trip. Visitors can use public transportation to reach the area and access the facilities within it on foot. TOD reduces emissions and fuel use by reducing the use of private cars and also provides a pedestrian-oriented experience that many people enjoy.

Complete Streets

“Complete Streets” programs encourage pedestrian and bicycle transportation and the use of public transportation by making it safer and more pleasant for people to walk, ride bicycles, and use public transit. The name means that streets are for everyone, not just motorized vehicles.

Examples of Complete Streets measures include creating bike lanes, improving street and sidewalk lighting, providing bicycle racks and showering/changing facilities for cyclists, changing zoning laws to encourage mixed-use development, and providing wide and conveniently spaced crosswalks for pedestrians. Encouraging alternative forms of transportation reduces emissions and fuel use, and also facilitates a variety of experiences not possible in automobile-oriented environments.

Commuter Options

Creating new options to expand commuter choices encourages people to use transportation options other than treating driving as the default transportation solution. Some are best implemented directly by the government; one example is building park-and-ride lots to reduce traffic into the city center. Others may be better implemented by employers, although governments can provide incentives for the adoption of these programs (and, of course, governments are also employers themselves).

Examples of the second type of program include carpool and vanpool services, including rider matching; provision of preferred parking spaces for pool vehicles and financial incentives for employees to use a carpool or vanpool to commute to work; subsidized transit passes, possibly coupled with increased parking fees, to encourage employees to use transit rather than driving to work; and guaranteed ride home services, which provide emergency transportation to those who normally use public transportation or shared-ride programs and may need transportation after hours. These programs may save the employer and the city money by reducing parking space requirements, congestion on roads, and emissions and fuel use.

Telecommuting programs allow employees to work at home one or more days per week, thus eliminating the need to drive to and from their usual workplace. By taking some commuters completely out of the transit marketplace for at least part of the workweek, telecommuting reduces the load on the entire transit system. In addition, employees save the time they would have spent commuting, and employers do not have to provide parking for the days the employees work from home.

Sometimes combined with telecommuting, workplace flexibility programs allow employees some flexibility in the days and times in which they work. These programs reduce the strain on the transit system by allowing employees who commute to work to avoid peak hours of travel, thus reducing travel time and congestion as well as reducing emissions and fuel use. Nonstandard scheduling may have a similar effect. For example, some government offices have spread a 40-hour week over four days (10 hours per day) rather than five, thus reducing by one the number of days an employee needs to commute to work and also

shifting the hours employees commute away from peak periods of travel.

Other Approaches

Incident management systems focus on reducing traffic congestion by quickly clearing stalled or crashed vehicles from the road. Incident management systems are generally applied to highway systems and include the creation of roving tow and service vehicles, as well as a system of motorist call boxes or dedicated phone numbers to call for aid.

Value pricing systems force drivers to pay the full cost of services they consume and thus encourage the use of alternative forms of transportation. For instance, instead of offering subsidized parking, companies could be encouraged to price parking at its true cost. Congestion pricing is a similar concept; by charging motorists more to drive into an area or to park during the hours when demand is highest, drivers are encouraged to find other means of transportation or to make nonessential trips during nonpeak traffic periods.

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See Also: Bicycle Commuting; Bicycle Facilities; Bus Routes; Car Sharing; Carpooling; Complete Streets; Congestion Management and Air Quality Program; High Occupancy Toll Lanes; High Occupancy Vehicle Lanes; Livable Streets; Park-and-Ride/Kiss-and-Ride Lots; Shared Taxis; Transit Systems; Transit-Oriented Development.

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Transportation Cooperative Research Program

The need to meet expanding mobility, environmental, and energy demands in the United States has placed a heavy burden on the nation's public transportation systems. Existing public transit systems increasingly must find ways to expand services, improve efficiencies, and evolve aging fleets. These activities require a sound foundation in research in order to effectively address operating issues, apply new technologies, and deliver innovative solutions to meet today's transportation requirements.

The Transit Cooperative Research Program (TCRP) was established under the Federal Transit Administration (FTA) in 1992 to help the U.S. transportation industry accomplish those goals by providing transit research in the areas of policy, planning, equipment, services, operations, administration and maintenance. The TCRP's research reports provide comprehensive but concise information that transit professionals and agencies use to solve transportation-related problems, implement innovations, streamline processes, optimize resources, and reduce costs.

Program Participants

The FTA sponsors the TCRP, which received \$6.5 million in federal funding for research in fiscal

year 2012. Operations of the research program are managed by the TCRP Oversight and Project Selection (TOPS) Committee with the administrative support of the Transportation Research Board (TRB), a unit of the National Research Council of the National Academies. The TCRP's research is conducted with the assistance of state and local government officials, transportation industry professionals, transit equipment and service providers, and diverse research organizations. The American Public Transportation Association (APTA) acts as the program's liaison with the transit community.

Each research project is assigned to a dedicated panel appointed by the TRB that is responsible for providing technical guidance throughout the project's life cycle. The panels are comprised of voluntary members who are industry professionals and researchers and, when possible, represent in some way the project's targeted demographic. The panel members draft the specific project statements and select contractors based on their proposals submitted through an open process that enables all research agencies to compete for the project work based on their technical merit. The process ensures that the TCRP has access to the best talent available for each project.

In selecting contractors to work on the TCRP's research projects, the panel members evaluate submitted proposals according to six key criteria: demonstrated understanding of the research problem; merit of the proposed research methodology and design; demonstrated experience, qualifications, and objectivity in the same or similar research area as the project; specified plan for the application of research results; inclusion of small business enterprises owned or controlled by women or minorities; and adequacy of research facilities. The panel also considers potential sources of bias and conflict of interest among contractor candidates that might jeopardize the integrity of the research activity and final report.

Once a TCRP report is completed, the primary objective of the program is to disseminate the results to the intended end users of the research, such as transportation agencies, service providers, suppliers, and other interested parties. The APTA has the lead role in ensuring that the TCRP research results are made available to the relevant constituents via conventional channels, as well as through more interactive means. The APTA conducts field

visits, workshops, training, and other activities to disperse the TCRP results and facilitate understanding and action by transportation industry professionals.

Areas of Research

Anyone can submit a request for TCRP research to the TRB at any time. Requests are evaluated by the TOPS committee to ascertain research scope, required funding levels, and expected outcomes. Each request is then prioritized based on how well the research aligns with and supports the strategic research goals of the TCRP and the FTA. The strategic goals are focused on two key areas: increasing livability for American citizens and improving the performance of transit operations and systems in the United States.

In the area of increasing livability, the FTA conducts research aimed at helping transit agencies enhance transportation services in their communities. Types of research that would come under this strategic category vary widely. Examples include projects that help determine infrastructure improvements that could be utilized to enlarge transit capacity, projects that help identify cost-assessment tools that could be used to illustrate financial impact of ridership levels, and projects that investigate new technologies, marketing approaches, or capacity innovations.

In regard to improving the performance of transit operations and systems, the FTA focuses on research that supports the accessibility, reliability, efficiency, safety, and affordability of public transportation for all individuals throughout the United States. Research in this area might address technologies and approaches that can improve the planning, design, construction, management, maintenance, and utilization of transit systems and that maximize transportation investment dollars while reducing risks and uncertainties.

Safety, mobility, and sustainability research also fall under the FTA's performance improvement goal. This type of research might include methods to improve emergency preparedness among transportation organizations and professionals, reduce transit-related emissions and energy dependence, or increase access to transportation services for the disabled, the disadvantaged, and the elderly.

Within the strategic framework set by the FTA, the TCRP has its own set of objectives and priorities

that reflect the organization's principles and direct its actions. Foremost, the TCRP has committed to placing transit customers first, followed very closely by the community as a whole. The rationale is based on the belief that the transportation industry cannot prosper if it fails to meet the changing and expanding demands of the U.S. consumer.

The TCRP also strives to support the integration of advanced technologies into all aspects of public transportation to ensure that changing mobility needs among consumers and within communities are appropriately met. More broadly, the TCRP has pledged its ongoing support to improving public transit systems and experiences throughout the nation via continuous development and enhancements.

The organization also recognizes the expanding role state and local officials have in setting and allocating transportation funding dollars. As a result, the TCRP has made it a goal to help the transportation industry work more collaboratively with government and community programs to optimize opportunities related to community planning initiatives and intermodal transit (that is, transportation by more than one means of delivery). The fifth and final stated goal of the TCRP is focused on revitalizing transit organizations themselves to take best advantage of information technology progression, workforce evolution, and new roles and alliances within the transportation industry as a whole.

Synthesis Program

In addition to its cooperative research reports, the TCRP also encompasses several subprograms designed to support transportation-related research and facilitate sharing of transit-focused information. The Synthesis Program, for example, is dedicated to amalgamating the best available knowledge about topics of concern to the transportation industry. To ensure the inclusion of significant and relevant knowledge, the program taps numerous sources that serve as a storehouse of information regarding transit concerns. A great deal of the warehoused information is the result of prior research and real-world application of solutions among transit industry professionals.

While the knowledge readily exists, there was a lack of a formal channel for compiling and sharing the data until the TCRP implemented the Synthesis of Transit Practice report series as part of the Synthesis Program. Under the program, the TCRP

collects and assembles the various forms of information into concise reports pertaining to specific transit problems and associated issues and makes recommendations for action where appropriate.

Transit IDEA Program

The Transit IDEA (Innovations Deserving Exploratory Analysis) Program is another subprogram of the TCRP. It provides start-up funding for innovations in surface transportation systems that would be unlikely to receive financial backing through conventional sources. The program is primarily focused on research that is dedicated to finding ways to increase transit use; improve transportation safety, security, and emergency preparedness; increase transit capital and operating efficiencies; and promote environmentally friendly transportation practices, such as increased energy independence.

Since 1994, the TCRP has sponsored an International Transit Studies Program (ITSP) aimed at expanding the professional development of U.S. transportation professionals by providing them with opportunities to learn from transit systems in other countries. The intent is that those professionals will return to the United States with new perspectives and knowledge that could be applied within their own organizations and among their peers across the country.

The IDEA program sponsors two international study missions annually in which teams of U.S. public transportation professionals visit successful transit operations abroad. Each study mission lasts for two weeks and centers on a key issue of concern in public transportation. The locations for the site visits are chosen based on the host company's ability to illustrate new concepts or innovative approaches to addressing the public transportation challenges outlined in the IDEA study mission.

As part of the program requirements, each participant—selected on the basis of an open nomination process—must prepare a trip report upon return that speaks to an element of the mission agreed to in advance by the IDEA group. The participants' reports are consolidated into a single mission report for TCRP publication and distribution to transportation industry professionals.

Other Subprograms

The TCRP's Legal Research Digest Program researches and reports on issues tied to

transportation and intermodal law. The reports are designed to provide transit attorneys with reliable, targeted information about environmental standards and requirements; construction and procurement contract procedures and administration; civil rights and labor standards; and liability, risk management, and system safety issues having national significance to the transit industry.

An additional subprogram of the TCRP includes the Quick Response for Special Needs Program, which is a specially funded program that provides a mechanism for responding rapidly to research problems that require swift or immediate attention based on the assessment of a TOPS task force.

All the TCRP's programs combine to provide an invaluable resource for the U.S. transit industry. According to an awareness and advantages survey performed by the TCRP at the end of 2002, the majority of respondents (85 percent) considered the Transportation Cooperative Research Program to be beneficial, both individually and industry-wide. Comments solicited from respondents revealed that the TCRP's research was used extensively by industry professionals. The respondents indicated that the TCRP's research had helped them to significantly reduce the time, cost, and staffing resources needed to obtain important background information on transit issues, and that they used the TCRP research to support decision making and training.

Approximately 20 percent of respondents also reported direct cost savings totaling nearly \$13 million as a result of using the TCRP's information reports and research services. As of May 2013, the TCRP had published more than 600 research reports to benefit the U.S. transportation industry.

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See Also: American Public Transportation Association; Federal Transit Administration; Transportation Research Board; Transportation Statistics and Databases; Transportation Studies.

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Transportation Equity Act for the Twenty-First Century

The Transportation Equity Act for the 21st Century (TEA-21), passed in May 1998, largely kept the provisions made by its predecessor, the Intermodal Surface Transportation Efficiency Act (ISTEA), for federal transportation legislation concerned with providing funding flexibility to states and encouraging balanced investment in highway, transit, intermodal transportation, and technological projects to ensure integrity of all transportation systems in the United States.

Among TEA-21's important changes from ISTEA were the guaranteed funding of Highway Trust Fund (HTF) revenues for surface transportation, guaranteed 90.5 percent return to states on revenues paid into the HTF, the continuation and expansion of environmental programs created by ISTEA, strengthening of planning requirements, expansion of the flexible funding provisions, and a stronger emphasis on safety. The major debates surrounding TEA-21 centered on fair distribution of funds among states and the appropriate size of federal support. Delays in passage, a highly partisan process, and a greater degree of earmarking than previous legislation marked the legislative process.

The Legislative and Political Process

ISTEA, the omnibus federal funding legislation originally passed in 1991, was set to expire on

October 1, 1997. By late 1996, discussion of the next transportation bill largely concerned distribution of federal funding for the states. In 1995, the returns per dollar contributed to the HTF varied from 56 cents in South Carolina to \$6.40 in Alaska. “Donor” states argued for overhauling ISTEA funding formulas to give them a fairer share. While most recognized that heavily rural states lacked the population density to fund their highway systems fully, many argued that the range should be narrowed.

The STEP 21 coalition (representing 21 states) wanted to adjust ISTEA formulas to guarantee 95 cents return per dollar contributed the HTF and to consolidate most ISTEA programs into a block grant to allow states even greater spending flexibility. A smaller coalition of states argued for devolution of almost all highway and mass transit policy to states.

Meanwhile, the Alliance for ISTEA Renewal, a group of mayors, county governments, city governments, metropolitan planning organizations (MPOs), and the Surface Transportation Policy Project, argued for minimal changes from ISTEA. On the other hand, oil, automobile, and trucking companies lobbied to increase state government officials’ power in project selection via a flexible block grant.

President Bill Clinton’s proposal, the National Economic Crossroads Transportation Efficiency Act (NEXTEA), called for a \$175 billion, six-year plan that largely retained ISTEA’s objectives. However, in Congress, efforts to negotiate federal transportation legislation collided with the Republican Budget Committees’ promise to balance the federal budget by fiscal year 2002. Their agreement to only \$125 billion funding over five years generated opposition from both House and Senate Transportation Committees, who were in the process of working on their respective bills.

Following months of deadlock, both committees passed bills exceeding agreed budget spending limits in September 1997; however, Senate filibustering over campaign finance reform left insufficient time to deal with the transportation legislation during the year’s final session. Both houses agreed to extend ISTEA through May 1, 1998, through a reauthorization called the Surface Transportation Extension Act of 1997 (short-TEA).

Following the post-recess announcement that higher-than-anticipated revenues would mean a

projected budget surplus, both houses passed bills with larger funding proposals: the Senate’s ISTEA-II and the House’s Building Efficient Surface Transportation and Equity Act (BESTEA).

TEA-21, the reconciled bill that emerged from conference, comfortably passed both houses of Congress on May 22 and became law on June 9, 1998. Because of errors made in the rush to pass the legislation before the Memorial Day recess, technical corrections known as the TEA-21 Restoration Act were made and voted into law shortly thereafter.

Content and Implementation

TEA-21 authorized approximately \$218 billion in total transportation spending over six years (fiscal years 1998 through 2003) with \$167.1 billion designated for highways and \$36.3 for mass transit. It also continued all the major ISTEA programs and added a number of new programs to meet specific safety, economic, environmental, and community challenges.

TEA-21 retained ISTEA’s core spending category structure. The five major funding mechanisms under the Federal Aid Highway Program included the National Highway System (NHS), the Interstate Maintenance (IM) system, the Surface Transportation Program (STP), the Bridge Replacement and Rehabilitation (BRR) program, and the Congestion Mitigation and Air Quality (CMAQ) program. Most mass transit funding was in the form of grants, the largest of which was the Urbanized Area Formula (UAF) Grant.

The \$28.5 billion funding for the National Highway System (NHS) accounted for about 13 percent of TEA-21 funding. These funds could be used for the major highway system, including the interstate system and principal arterial roads designated as necessary to the national economy and defense.

The formula allocating these funds among states included state percentages of NHS non-interstate lane miles, vehicle miles traveled, diesel fuel, and population. The approximately 11 percent of TEA-21 funds allocated to the IM program was for exclusive use on the interstate system. The 15 percent of TEA-21 funds allocated for the STP could be used flexibly for projects including roads, intermodal infrastructure, environmental improvements, research, or planning. The BRR and CMAQ programs were funded at \$20.4 billion and \$8 billion, respectively. BRR funds could be used for any

bridge on a public road. CMAQ funds, distributed based on the percentage of a state's residents living in polluted areas, could be used for any project intended to meet air quality standards.

Two of the most significant achievements of TEA-21 were the guaranteed funding and the continuation and expansion of environmental programs created by ISTEA. TEA-21 also strengthened the planning requirements, expanded the flexible funding provisions, and placed a stronger emphasis on safety.

TEA-21 created a "firewall" around the HTE, changing the rules to ensure that its spending would be separate from general defense and discretionary spending categories. With this firewall, reduced spending for transportation could not be used to increase spending for other domestic discretionary programs, thus eliminating the principal incentive for reducing transportation spending.

The firewall amount linked directly to projected receipts into the HTE, guaranteeing specific amounts of funds to be spent on surface transportation and transit. Furthermore, to meet the demands for better spending equity, TEA-21 guaranteed states 90.5 percent return on revenue paid into the Highway Trust Fund.

To add a stronger environmental emphasis, TEA-21 created a new program, the Transportation and Community and System Preservation Pilot Program, to support planning for environmentally friendly development by states and localities. The key purpose of this program, created in response to increased interest in smart growth, was to devise innovative neighborhood, local, metropolitan, state, or regional strategies that would improve the efficiency of the transportation system, minimize environmental impacts, and reduce the need for costly public infrastructure investments. TEA-21 also created an environmental streamlining pilot program to reduce red tape and paperwork in project reviews without compromising environmental protections.

TEA-21 did not heed the highway lobby's pressure to decrease MPO and local officials' power relative to state transportation agencies. Rather, TEA-21 retained the general structure of the planning process for metropolitan areas and states as enacted by ISTEA, but streamlined the planning processes and specifically included freight shippers as stakeholders in the planning process. To streamline the planning process, TEA-21 consolidated the

16 factors and criteria used in project planning into seven broad factors. TEA-21 also retained the fiscal constraint provision of ISTEA.

TEA-21's substantial changes for safety programs included increased funding for safety, greater flexibility in using categories of funding for a wide variety of safety-related efforts, new programs to promote seat belt and child safety seat use, and tough new measures to target repeat drunk drivers and to ban open alcohol containers in cars.

TEA-21 created a \$500 million Safety Incentive Grant for which states enforcing a 0.08 blood alcohol concentration limit would be eligible. One of the seven new planning criteria was safety and security for both motorized and nonmotorized users, which brought pedestrian and bicycle safety features into more prominent focus.

Furthermore, the railway-highway crossing program opened hazard elimination measures to a broader range of infrastructure, including interstate highways, public transit facilities, and bicycle or pedestrian pathways. The act also restructured the Motor Carrier Safety Program to allow states flexibility in tailoring commercial motor vehicle safety solutions to meet their individual needs.

Beyond these major changes, TEA-21 had other substantive provisions and impact. Two new programs, the border crossings and trade corridors programs, were intended to ensure the country's continued transportation advantage and allow it to compete effectively in the global arena. These programs would support trade, improve border security, and facilitate the design and construction of corridors of national significance.

A new State Infrastructure Bank pilot program was created under which four states (California, Florida, Missouri, and Rhode Island) were authorized to enter into cooperative agreements with the federal Department of Transportation to set up infrastructure revolving loan funds. The Transportation Finance and Innovation Act of 1998 created a new \$530 million credit assistance program to help leverage \$10.6 billion for construction of projects of national importance, such as intermodal facilities, border crossing infrastructure, and expansion of multistate highway trade corridors.

Legacy

TEA-21 largely continued the momentum from ISTEA's policy changes. TEA-21's successor, the

Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) continued this policy emphasis shift from building and maintaining highways toward managing a performance-driven, intermodal system.

With TEA-21, states were given a higher degree of flexibility and had the opportunity to make revolutionary changes to their transportation spending patterns. While in the early years of TEA-21 implementation, the trend away from using federal funds for new highway construction and toward maintenance and intermodal projects appeared to be reversing, scrutiny revealed that much of the escalation in new highway spending came from just one project, the “Big Dig,” Boston’s Central Artery/Tunnel Project.

The late 1990s TEA-21 implementation period represented one of only a few periods when mass transit use in the United States grew faster than automobile use. Federal spending on pedestrian and bicycle infrastructure, while remaining small compared to the overall program costs, also increased from less than \$7 million per year before ISTEA to over \$400 million in 2003.

ISTEA and TEA-21 also remarkably increased spending on transportation planning and administration, more than tripling it in the 1990s. These costs directly relate to the new planning requirements that greatly expanded the number of stakeholders involved in decision making, broadening participation beyond the previous structure of a small number of engineers, contractors, and government officials.

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See Also: Congestion Mitigation and Air Quality Program; Federal Aid Highway Program; Federal Transportation Policy; Highway Trust Fund; Intermodal Surface Transportation Efficiency Act; National Highway System Designation Act of 1995; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Surface Transportation Policy Project; Surface Transportation Program; Transportation, Economics of.

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Transportation Impact Analysis

Transportation impact analysis (TIA), also known as traffic impact analysis, is a type of engineering study used as a tool to determine potential surface traffic impacts of a proposed development. The complete analysis can be used to forecast future effects from existing and proposed development projects and to predict the useful life of a transportation project across expected future land use scenarios. These studies are also used to help evaluate whether a proposed development is appropriate for a site and what type of transportation improvements may be necessary.

Significance and Process Components

Better decisions can be made when impacts are accurately projected through the traffic analysis process. Mindful planning results in less future traffic congestion, fewer safety issues, milder environmental impact, and avoidance of unnecessary and costly improvements.

The major elements of a TIA include existing conditions analysis, estimation of future traffic with and without development, analysis of traffic impacts, and recommended roadway improvements. A number of variables are involved in, and data collected for, the assessment, depending on the type, size, and location of development proposed. These typically include trip generation rates, trip distribution, peak morning and evening traffic flows, intersection capacity, vehicle demand, turning movements, and mitigation.

Some impact studies include data on transit, pedestrian, and bicycle traffic, as well as on parking, freight loading, and construction activities.

Depending on the municipality and state in which the development is proposed, specific process guidelines are available for developers and transportation authorities.

Examples and Models

The study area of a site is determined and the project setting and description are compiled. These include existing and proposed total gross square footage for each land use type, description of existing transportation infrastructure, and description of change in function of lanes, public rights-of-way, and access sites. The initial overview should identify study issues, needs, assumptions, procedures, available sources of data, past and related studies, report requirements, and other topics relevant to prepare the analysis.

Other considerations during the overview phase of any development project are horizon year of buildout related to the proposal; other developments currently approved or under way; number, locations, capacity, and safety issues related to access points; and potential mitigation opportunities.

After the initial information is compiled, a travel demand analysis and traffic impact analysis need to be performed. Data collection and interpretation will usually include trip generation and distribution rates. Trip generation (simply put: in-and-out traffic) is the estimate of daily person-trips for an average weekday generated by households within each study area.

The *Trip Generation Manual* published by the Institute of Transportation Engineers (ITE) is often used as a guide and handbook to calculate these rates. Mainly, estimates are determined by data on weekday morning peak-hour and weekday evening peak-hour trips in residential areas.

There are typically two types of use for trip generation rates: (1) a transportation planning process that involves large zones of urban areas, with a goal to forecast the number of trips that will begin from or end in each travel analysis zone (TAZ); and (2) planning or forecasting based on trips made to a particular land use site, with a goal to determine impact of development, or land use changes.

For transportation planning, zonal trips are estimated for a variety of trip purposes: work trips, school trips, shopping trips, and social or recreational trips. Models may be zonal or household based. Person-trips may include pass-by trips

(trips attracted from existing traffic on adjacent streets), such as stops made at banks, service stations, and convenience stores; and link-diverted trips (trips produced from the traffic on roadways within the vicinity of the generator, and require a diversion).

Trip distribution is a model of the number of trips that occur between each origin zone and each destination zone, estimated by trip generation data. Trip distribution models strive to predict the number of trips that will be made between a pair of zones for a particular trip purpose.

There are various models of trip distribution. However, most of the models incorporate the same basic factors that affect the number of trips between an origin zone and a destination zone. The factors are: the number of trips produced by the origin zone, the degree to which the attributes of the destination zone attract trip makers (attributes that gain importance vary with the trip purpose), and the factors that inhibit travel between a pair of zones. These factors could be travel time, travel distance, and travel cost.

After data are collected and analyzed for traffic demand and impact, other existing information is added to the compilation: roadway and intersection geometrics such as roadway width, number of lanes, lane configuration at intersections, and channelization; accident data; traffic control device inventory such as signal timing and phasing, stop signs, and yield signs; and land use code(s) selection and application.

Level of service for signalized and nonsignalized intersections should be in accordance with the latest edition of the *Highway Capacity Manual* published by the Transportation Research Board (a division of the U.S. National Research Council).

New Strategies

The technical methods to estimate how much traffic a new development will create have been standardized and are used by traffic engineers across the country. These methods are generally based on data collected from single-use, automobile-dependent, suburban sites. They do allow for some internal capture (trips that might be entirely within larger, mixed-use developments), but in general the methods do not adequately account for the effects of compact development, mix of uses, site design, walkability, transit, or regional accessibility, which

are all key elements of smart growth strategies and sustainable communities.

Recent research has shown that neighborhoods that mix land uses and that are near other developments allow residents and workers to drive significantly less if they choose. Research also shows that in the most centrally located, well-designed neighborhoods, residents drive as little as half as much as residents of outlying areas. An added benefit is that pedestrian and biking traffic tend to be safer. Along with these benefits, mixed-use development can improve communities in other important ways, including supporting affordable housing by lowering transportation costs for residents.

Currently, leading researchers and practitioners in transportation and development are designing new methods to estimate traffic impacts of mixed-use developments. They are looking at how various land use factors such as density, regional accessibility, and roadway connectivity affect travel behavior, including per capita vehicle travel, mode split, and nonmotorized travel. The goal is to achieve planning objectives such as consumer savings, emission reductions, improved public fitness and health, and habitat protection, all allowing for smart urban growth.

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See Also: Benefit–Cost Analysis of Transportation; Risk Analysis/Assessment; Spatial Equity Analysis; Traffic Demand Management; Traffic Engineering; Transportation Planning; Trip Distribution Models; Trip Generation Rates and Models; Urban Transportation Planning Process.

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Transportation Impacts on Land Use

Land use refers to the human use of land, which can be described from two perspectives: functional, which is concerned with social and economic activities taking place at the specific geographic location, and formal, which is concerned with the spatial pattern. The functional perspective is to segregate use categories that are thought to be incompatible, such as residential, commercial, institutional, industrial, agricultural, forests, or parkland. The formal perspective can be evaluated using such attributes as density, clustering, mix, and connectivity.

Transportation impacts land use, both functionally and formally. Reliance on auto use, commonly seen in the suburban areas in the United States, contributes to low-density and expansive land development, as well as the segregation of different land use types. Convenient and reliable transit service allows a nodal urban form and often leads to high-density and mixed-use development. Pedestrian and bicycle facilities implemented in many cities—such as bike lanes, improved sidewalks, and

bike sharing programs—encourage walking and cycling, fostering pedestrian-oriented retail and service development.

The interaction between land use and transportation has long been recognized. Their relationship is often described as a chicken-and-egg problem because the causal links between transportation and land use tend to be intertwined. Land use changes travel demand, remolds accessibility, and thus influences transportation. Transportation, in turn, influences land price and shapes land use development patterns.

Although the effects of transportation on land use are largely moderated by long life cycles of land development and durable real estate stock, the impacts of transportation on land use over time are evident: transportation consumes land and shapes land development. In general, slow travel modes lead to the formation of dense city cores and the popularity of cars results in dispersed development.

Mobility Versus Accessibility

Mobility and accessibility are two key concepts used by transportation professionals when explaining the relationship between transportation and land use. These two concepts are similar because both measure transportation cost, which is an important factor for location choice. Households balance the money and time spent on their daily trips to work, shopping, and recreation with housing costs and other amenities. Firms seek lower transportation costs for their connections to suppliers, consumers, and employees. However, mobility and accessibility are significantly different concepts, and this has led policy makers to completely different notions in transportation planning.

Mobility measures the physical movement of people and goods and emphasizes the level of service of transportation systems, mainly focusing on the improvement of transportation supply. For professionals largely focused on improving mobility in the last century, the emphasis has been on transportation supply. As a consequence, significant increases in road and parking capacities have been observed. This has led to dispersed land use patterns.

In contrast, accessibility considers the ease or difficulty of desired goods or services to be reached, implying a more holistic consideration

of land use and transportation systems. In recent years, accessibility has gradually been adopted by more practitioners. Examples of efforts to improve accessibility can be seen in several cities. With mixed-use land development and the integration of multimodal transportation, planners are able to control urban sprawl and revitalize city cores.

Direct Impacts Versus Indirect Impacts

Transportation affects land use, both directly by consuming land for transportation facility development, and indirectly by changing accessibility and influencing land development. In a recently updated report, researchers carefully examined the impacts of transportation on land use. As far as direct impacts, an estimated 0.7 percent of the continental United States is devoted to road rights-of-way, and 0.4 percent of the land is paved for roads. In addition, parking facilities cover a big portion of urban land, especially in commercial use.

The development of transportation facilities requires a change in land use to provide space for transportation construction. At the same time, land development relies on transportation supply, such as transit for apartment towers, parking lots for shopping malls, and transfer hubs for factories. These direct impacts between land use and transportation are easy to recognize.

In contrast, it is often hard to quantify transportation's indirect impacts on land use, especially in the long term, because changes in transportation conditions are often intertwined with changes in the economy, population, and other facilities. Each system is complex and dynamic, making it difficult to assess the exact land use impacts of a particular transportation project. Researchers and practitioners often resort to land use models for such assessments, and those models can capture some but not all effects. The overall assessment, therefore, must be based on a combination of modeling and professional judgment.

Urban Land Use Models

Many studies have been conducted in attempts to assess the interaction between land use and transportation. With the aid of this research, practitioners have been able to partially understand the impact of transportation policies and programs on land use. However, as some researchers concluded in a review of existing land use/land cover models,

no single land use model has yet successfully captured all the effects.

Some approaches are more common than others and they already have been used in the integrated models of land use and transportation. Examples include T. de la Barra's TRANUS (1989), J. D. Hunt and J. E. Abraham's PECAS model (2005), K. C. Clarke's SLEUTH model (2007), and P. Waddell's UrbanSim (2002). TRANUS and PECAS are both aggregate models with zones (typically census tracts or traffic analysis zones) as their observational units. They recognize spatial effects by controlling for results from a spatial input-output model. These models are more appropriate for examining the impacts of transportation policies on a macro level (for example, state or national level).

The cellular automata-based SLEUTH model consists of an Urban Growth Model (UGM) and Deltatron Land Use/Land Cover Model. SLEUTH simulates land cover change by recognizing the temporal and spatial context of each cell, but it only shares information across immediately adjacent cells. More dispersed interactions and correlations are largely ignored.

In addition, by relying on a rule-driven algorithm, SLEUTH is not designed to flexibly accommodate the effects of many influential human factors. Therefore, SLEUTH is more appropriate to simulate and predict land use changes without complex economic interactions, such as deforestation and desertification.

UrbanSim is currently the most widely adopted land use model. As an agent-based simulation system, UrbanSim can use grid cells or user-defined zones as its observational units. The land development modules in UrbanSim largely rely on standard, multinomial logit specifications to handle the discrete nature of land use type. The model controls for regional, neighborhood, and cell characteristics to diminish spatial effects.

Implication for Policy Makers

Given the influence of transportation on land development, public agencies have the power to induce land use change by providing infrastructure and implementing transportation-related policies. Many transportation developments and policies, such as road pricing, have caused significant changes in land use development, intentionally or unintentionally.

Seeing such connections, the U.S. Congress mandated that planning organizations consider the potential effects of transportation on land use through the Intermodal Surface Transportation Efficiency Act (ISTEA), which requires that transportation plans and programs be designed consistently with short-term and long-term land development plans. Later on, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) reconfirmed the requirement for all federally supported transportation plans and programs to consider land use.

The act states that they must "protect and enhance the environment, promote energy conservation, improve the quality of life, and promote consistency between transportation improvements and state and local planned growth and economic development." The Moving Ahead for Progress in the 21st Century Act (MAP-21), the latest federal law on transportation planning and policy, continues to emphasize the importance of integrated consideration of transportation and land use.

Emerging Issues

The development of technology and changing lifestyles in recent years have led to disputes over whether the impacts of transportation on land use are diminishing. For example, increasing telecommunication and online shopping make it easier for people to work, shop, and access amenities without explicitly paying for transportation. The perception that transportation costs have been eliminated in such situations may alter people's and firms' location choice behavior, reshaping urban land use patterns.

Most cities today already have large transportation capacity and real estate stock, moderating the impact of transportation changes on land use. In such a situation, a marginal change in transportation may not have an evident effect on land use. In short, as urban systems become more complex, these investigations of transportation's impacts on land use are becoming more challenging.

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See Also: Accessibility and Mobility; Intermodal Surface Transportation Efficiency Act; Transit-Oriented Development; Urban Transportation Modeling System.

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The TIP lists specific priority projects, financial allocations, and a tentative schedule of projects. The TIP is required by federal law (Moving Ahead for Progress in the 21st Century, or MAP-21, as of 2013) to receive and spend federal transportation funds and must cover at least the next four years. Every dollar spent by government agencies must undergo thorough scrutiny to ensure that the spending will provide benefit to the society.

The TIP allows federal, state, regional, and local government agencies to carry out such a scrutiny before consideration for funding. The TIP is developed by a collaborative process and ensures conformity with national air quality standards and state transportation improvement plans.

Need for the TIP

The U.S. federal government distributes funds to states and metropolitan areas based on the federal transportation law. Per federal law, every metropolitan area in the United States with more than 50,000 in population must have a metropolitan planning organization (MPO) responsible for preparing the Long-Range Transportation Plan (LRTP) and the TIP.

While the 20-year-horizon LRTP provides a vision for the transportation improvements for the region based on economic, land use, and demographic projections, the TIP provides a list of projects that are consistent with that vision. It is expected that the projects in the TIP will lead to the implementation of the vision put forward in the LRTP. It should be noted that the TIP represents an agency's intent to construct or implement a specific project and the anticipated flow of federal funds and matching state or local contributions. It is not a commitment.

Transportation Improvement Programs

The Transportation Improvement Program (TIP) is a financial program that describes the schedule for obligating U.S. federal funds for transportation to state and local projects such as highways, bridges, transit, freight, and nonmotorized transport such as bike and pedestrian improvements. It also includes set-asides for programs such as safety and intelligent transportation systems (ITS).

Contents of the TIP

The TIP lists all projects that intend to use federal funds, along with nonfederally funded projects that are regionally significant. The TIP can also include other state-funded capital projects, which are not required but are often shown for information purposes.

The TIP not only lists the specific projects but also documents the anticipated schedule and cost for each project phase (for example, preliminary engineering, final design, right-of-way acquisition, and construction). The projects in the TIP are expected to be implemented during the TIP period.



Bridge maintenance can be challenging, as there are only a few accurate techniques to test for integrity and safety. The Transportation Improvement Program (TIP) allots the scheduling of federal funds to projects such as maintaining or improving existing bridge infrastructures.

Time Span and Update

The list of projects in the TIP must be financially constrained to the amount of funds that are expected to be available. This means the TIP is not a “wish list” of projects but a realistic one. Projects that are not progressing might be removed from the TIP, and this makes the inclusion of projects in the TIP competitive.

Per the federal law, the TIP should cover a minimum of the next four years and follow the federal fiscal-year schedule. The usual practice is to cover the next five years and include a post-five year period, too. The TIP is updated every year in addition to adding amendments from time to time. The

approved TIP can be modified or amended in order to add new projects, remove projects, advance projects, and/or accommodate changes in cost, phase of work, or scope of a project.

Funding

The TIP is funded by a variety of sources, although the major source is the federal government. The federal transportation legislation authorizes the federal surface transportation programs for highways, safety, and transit. These programs are administered through the U.S. Department of Transportation’s Federal Highway Administration (FHWA) and Federal Transit Administration (FTA). The funds are provided through the Federal Highway Trust Fund (generated primarily from fuel tax).

These funds are apportioned among the states and metropolitan areas by formula. Most FHWA sources of funding are administered by the state departments of transportation (DOTs), while most transit funds are sent directly from the FTA to the transit operator. These funds are distributed as reimbursements for costs as they are incurred. Generally, 20 percent matching funds from the project sponsor are required by the federal law. Project sponsors can include states, counties, municipalities, private developers, toll authorities, and transit operators.

Development Process

The development of the TIP is a result of the transportation planning process and is the responsibility of the MPO. It is arrived at through a consensus-building process among state, regional, and local officials who are members of the MPO. This consensus-building process assures the federal and state governments that all interested parties have participated in the process and agree with the outcome.

As mentioned earlier, projects in the TIP are expected to realize a long-range vision. The municipal planners and engineers develop a list of projects based on their needs analyses and citizen complaints. If they think they need financial assistance, they bring the project to the MPO table for consideration.

MPOs solicit projects to be included in the TIP periodically. The MPO staff, with the assistance of experts from other regional and state agencies, as well as task forces and working groups, review and rank the projects based on various criteria agreed to by members of the MPO.

The projects may compete in a common pool or under different categories. Usually, the projects showing urgent need, higher benefit-cost ratios, and furthering the long-range vision (highest priorities of the region) get ranked highly. The MPO staff present the recommendations to the technical committee (planners and engineers from member municipalities and agencies) and the committee discusses and recommends the list (with any modifications agreed upon by the committee) to the MPO policy board (elected officials from member municipalities and representatives from participating agencies). The final recommendation is placed for public comment and any comments received within the stipulated time are incorporated into the TIP. This final TIP is then adopted for potential funding.

TIP and Air Quality

The Clean Air Act requires the U.S. Environmental Protection Agency (EPA) to establish the National Ambient Air Quality Standards (NAAQS) for various-criteria air pollutants. Areas where air quality monitoring shows a violation of the NAAQS are designated “nonattainment areas.”

By law, each nonattainment state is required to prepare a plan, known as the State Implementation Plan (SIP), that identifies how it will attain and/or maintain the NAAQS. The SIP is administered by the EPA through state environmental agencies.

In nonattainment states, TIPs must conform to the SIP. The MPOs and DOTs must demonstrate that the overall impact of the projects in a TIP will not have adverse impacts (that is, create new violations, increase the frequency or severity of existing violations, or delay attainment of the standards) in order to be approved for inclusion in the TIP.

Implementation

Once a project is in the TIP, the lead agency (county, municipality, state DOT, or transit agency) details the engineering aspects, design, right-of-way acquisition, and construction. The project will then be implemented according to its schedule.

Projects may be delayed because of a variety of reasons, including environmental issues and community concerns. These delays are identified and remedied as soon as possible. If required, appropriate amendments are made in the TIP to accommodate the cost or schedule changes. In the worst case,

a project might be removed from the TIP if there is no progress over a long time.

TIP and STIP

The TIP is different from the Statewide Transportation Improvement Program (STIP). The STIP is the state’s four-year transportation and capital improvements program. The STIP lists federally funded transportation projects that are located outside the MPO boundaries, in addition to incorporating the MPO TIP projects. The TIPs of MPOs are included in the STIP by reference without modification once approved by the MPO. The projects in the STIP include highway, bridge, public transit, bike, pedestrian, railroad, and other improvements. The STIP is prepared by the state DOTs.

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See Also: Highway Trust Fund; Metropolitan Planning Organizations; Moving Ahead for Progress in the 21st Century Act; National Ambient Air Quality Standards; Regional Transportation Planning Organizations; Regional Transportation Plans; State Transportation Planning.

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Transportation Modeling and Planning Software

Transportation models, defined as a simplified representation of a system, focus on selected elements

considered important for its understanding and analysis. They attempt to replicate the behavior of a system using mathematical formulations based on certain theoretical statements and observations. Although they are simplified representations, models may be very complex and often require large amounts of data and computational resources.

However, since the advent of low-cost and high-capacity computing, the uses of transportation modeling in enabling forecasts, evaluating alternative plans and scenarios, identifying the relationship between land use and travel patterns, and improving the decision-making process have been largely facilitated. Since the mid-1950s, when transportation modeling was first developed, several models and planning software have emerged.

Modeling Approaches

The general structure associated with transportation modeling was developed in the 1960s and has remained mainly unchanged despite major technological advances in the last decades. The approach concerns a sequence of four sub-models: trip generation, trip distribution, mode choice, and traffic assignment over a network.

Because travel decisions are not actually taken in this kind of sequence, several contemporary approaches on transportation modeling consider the simultaneous processes of trip generation, trip distribution, and mode choice. Other recent approaches focus on the activities of travelers and the choices they entail, aiming at a clearer understanding of travel behavior.

Model Taxonomy

Transportation models are classified in various categories in order to determine their appropriate use in the planning process and to identify their properties and differences. Their classification can thus be based on various dimensions.

A deterministic model does not include any randomness. Thus, an event can either occur or not occur. Repeated applications of a deterministic model will produce the same results. However, if certain attributes or inputs of the model are subject to any randomness (or not known with certainty), the model is defined as stochastic. In such models, different random number sequences will produce different results, indicating a probability of certain outcomes.

A model is defined as time-based when time advances from one point in time to the next based on constant steps. A model is event based when time progresses based on the occurring events, thus skipping certain points in time.

Off-line models are mainly used for evaluating what-if scenarios or testing various alternatives, while online models open up the possibility of continuous data input. If these data are real-time data, then real-time models can be developed that progress according to the rate at which time actually advances.

Real-time models are mainly used for managing and controlling traffic at real-time level (for example, traffic signal controllers) and are often attached to a physical traffic control device. Because computational requirements are considerably lower than those of real-time models, off-line models can simulate the behavior of a system at a rate often faster than real time.

Analytical models deal with the prediction of the performance of a system based on the validation, calibration, and statistical analysis of field data. If the modeled system has a logical structure and is not governed by discontinuities, an analytical solution can be obtained.

When analytical models are not applicable, simulation models are used. Such models use mathematical and numerical techniques for creating an inventory of possible events and assessing their impact for one or more variables of the model. However, they require a rather significant amount of input data, which in turn need to be validated and calibrated before used.

Static and dynamic models are differentiated based on the temporal nature of traffic flow and whether this is captured by the model. Static models are widely used in strategic transportation planning and analysis. They consider that origin-destination (OD) matrices, describing travel demand, are fixed over time and do not change throughout the duration of the analysis period, are inputted only once, and thus imply a steady state of traffic loading.

In contrast, dynamic models can describe time-varying networks and demand interactions using a behaviorally sound approach, and they can capture the temporal nature of traffic phenomena, such as congestion. Such models also consider that OD matrices can vary over time and depict the behavior of a system in a more realistic way.

Most models capture changes in the OD matrices once for every hour (hourly step), while some allow changes in shorter time intervals (for example, five- to 15-minute steps).

Since the advent of intelligent transportation systems (ITS), and the need for modeling the provision of travel information and guidance according to real-time conditions, the development of models accounting for flow changes relevant to time has emerged vigorously.

Macro-, Micro- and Mesoscopic Models

The most frequently used method for classifying transportation models is based on the level at which traffic flow conditions are represented and the details a model takes into consideration. Macroscopic models deal with the representation of traffic flow in a fluid aggregated way. As such, they include a limited amount of detail, which accounts for their ability to execute quickly and in a computational resourceful way. Such models focus on large geographical areas and usually consist of a large number of components (for example, zones, nodes, links).

Microscopic models deal with the movement of individual vehicles in an examined network and their in-between interactions. Such models incorporate the logic and methods according to which vehicles move laterally (lane-changing theory) and longitudinally (car-following theory), and how they accelerate, decelerate and change lanes. Microscopic models include a significant amount of details and data and are thus more computationally demanding than macroscopic models. They focus on evaluating the performance of a selected facility rather than the whole system, and thus focus on small geographical areas.

Mesoscopic models are models characterized by both macro- and microscopic features. Such models consider the movement of clusters or platoons of vehicles and also model their interaction, but do not take into account lane changing or other vehicle behaviors.

Planning Software

There exists an important distinction between transportation planning models and transportation planning software packages. While models serve as analysis tools necessary for study, design, and evaluation of typically large-scale and complex

transportation systems, software packages are tools that implement transportation planning models. As such, they usually include several sub-models, represented by different mathematical formulations, depending on the nature of the model itself. The software packages that are presented here are broadly classified based on the included level of detail (macro-, micro- and mesoscopic) and the applications for which they are mostly used. Because application areas are not completely distinct, many software packages often fall under more than one category.

Macroscopic Software Packages

VISUM is a macroscopic model that allows the modeling of all types of private and public transport types in one single integrated model, as well as the management of geographic information system (GIS)-based data. The software includes several sub-models associated with the four-step modeling approach and is currently widely used for a series of applications, including the overall planning and analysis of networks, the prognosis of impacts of road tolls, and the design and analysis of public transport timetables.

TRANSCAD is a transportation planning software at a macroscopic level, initially developed as a GIS, which also combines transportation modeling capabilities in a single integrated platform. It can be used for all modes of transportation, at any scale or level of detail. It is widely used as a tool for building transportation information and decision support systems, and it fully integrates GIS with demand modeling and logistics functionality.

CUBE is a suite of transportation modeling that encompasses various sub-models for working at different levels of detail. CUBE Voyager works according to the traditional four-step modeling approach or with any model type that uses highway assignment. CUBE Dynasim is a microscopic simulation model developed for detailed analyses and studies of selected areas.

QRS II/GNE package is used for a variety of purposes, including regional transportation studies, site impact analysis, transit planning, and database analysis. The GNE refers to the General Network Editor, which provides the means to input and read network-based data (node and link characteristics). QRS II stands for Quick Response System II and runs the four-step planning process—trip generation,

trip distribution, mode split, traffic/transit assignment—for highway and transit forecasting.

TRANSYT (TRAFFIC Network Study Tool) is a deterministic simulation and optimization tool used for modeling traffic in signal-controlled areas. The model looks for a combination of signal timings that minimize overall vehicle delay and coordinate signal controllers in such a way that clusters of vehicles can pass without stopping.

NETFLO (NETwork traffic FLOW simulation model) simulates traffic conditions both at a stochastic, event-based level and at a deterministic time-based level. NETFLO and FREFLO, a macro freeway model, are now integrated in a single simulation system CORFLO.

FREQ is a deterministic simulation model for freeway corridors, ramp metering, and high occupancy vehicle (HOV) facilities analysis and evaluation. Its main weakness lies in the simplification of arterial alternatives and lack of full rerouting techniques.

KRONOS is a simulation model developed for freeways, which incorporates a continuum model for representing traffic flow while also modeling lane changing, merging, and spillback behaviors, which are not included in other macroscopic freeway software.

CORQ (CORridor Queuing) is a dynamic traffic assignment model developed for freeway corridors. Its main weakness lies in the expression of the travel-time relationship as a static step function of link flows. The time relationship is insensitive to changes in signal timings on parallel arterials. Because CORQ was perhaps the most detailed corridor-level model throughout the 1980s, parts of its modeling approach were modified and incorporated into the design of the area-level integrated network simulation models INTEGRATION.

Microscopic Software Packages

VISSIM is a microscopic, simulation-based model developed for analyzing various road categories and urban networks. The software can model all modes of transport because it adopts several methods and theories that describe each separate mode. Although links are used in the model for describing road segments, VISSIM does not follow a node structure. Within VISSIM, a signal state generator (SSG) is included. The SSG allows the evaluation of impacts of several signal operations found in

the real world (for example, adaptive control, fixed time, actuated).

TRANUS is an integrated land use and transport modeling package combining a state-of-the-art model of activities location and interaction, land use, and the real estate market with a comprehensive multimodal transport model. The combination of these two models produces the highest benefits, but the transport model may be used as a stand-alone component, especially for short-term projections.

AIMSUN is a tool that integrates in a single software application the three types of transport models: static traffic-assignment tools, a new mesoscopic simulator, and a microsimulator.

Quadstone Paramics is a traffic and pedestrian microsimulation software for planning, designing, and analyzing transportation network performance, allowing operational assessment for current and future-year traffic conditions.

SYNCHRO's software suite is a complete solution for modeling, optimizing, and visualizing traffic networks. Using Synchro Studio and Warrants, traffic professionals can easily analyze capacity and timing optimization, as well as simulate, check, and fine-tune traffic signal operations.

NETSIM (NETwork SIMulation) is a microscopic model for a wide range of complex, multimodal traffic networks. Initially released in the 1970s, it provides a high level of detail using an interval-scanning simulation approach for the movement of individual vehicles, according to the car-following theory.

TRANSMODELER is a versatile traffic simulation package applicable to a wide array of traffic planning and modeling tasks. It can simulate all kinds of road networks, from freeways to downtown areas, and can analyze wide-area multimodal networks in detail. TransModeler models the dynamic route choices of drivers based upon historical or simulated time-dependent travel times, and also models trips based on origin-destination trip tables or turning movement volumes at intersections.

CARSIM (CAR-following SIMulation) models the behavior of individual vehicles on freeways according to car-following theory.

FREESIM is a stochastic simulation model based on a set of algorithms that simulate vehicle lane-changing and car-following behavior.

SCOT (Simulation of CORridor Traffic) is one of the first models for integrated networks. The software consists of two models, UTCS-1 (dynamic

traffic assignment at mesoscopic level) and DAFT (microscopic). The basic element of the model is its ability to integrate features from the two sub-models.

CORSIM is a microscopic simulation model designed for the analysis of urban networks and freeways. The model consists of two sub-models, namely FRESIM and NETSIM. A traffic assignment model is integrated in CORSIM for obtaining paths for given OD matrices.

INTEGRATION is a microscopic model of integrated freeways and urban networks, where individual vehicles' information (origin and destination) are input to the model. However, the routing of vehicles and their respective travel times are derived within the simulation. INTEGRATION is one of the first models to consider the interaction of ITS in vehicle guidance and routing.

Mesoscopic Software Packages

AIMSUN integrates in a single software application three types of transport models—traffic assignment models, a mesoscopic simulator, and a microsimulator. The microscopic model is developed based on car-following, lane-changing, and gap-acceptance algorithms. However, the new mesoscopic simulator in AIMSUN 6 provides an additional option to practitioners to model dynamic aspects of very large networks and removes most of the calibration burden when compared to a micro-simulator.

EMME is a transportation planning software package able to conduct complete travel demand modeling for urban, regional, and national transportation forecasting. Emme also includes a public transport model consisting of a combination of several analytical computer programs.

DYNUST (DYNAMIC Urban Systems for Transportation) is a simulation-based dynamic traffic assignment tool for regional operational planning analysis. Within DYNUST, the traffic assignment process includes the interaction of the simulation model and the time-dependent shortest-path module. DYNUST is based on an Anisotropic Mesoscopic Simulation (AMS) model deriving from previous models adopting a vehicle-based mesoscopic traffic simulation approach.

DYNASMART (DYNAMIC Network Assignment-Simulation Model for Advanced Roadway Telematics-Planning version) is a mesoscopic simulation model that includes demand-forecasting procedures for planning functions, as well as traffic

simulation models with dynamic traffic assignment and other operational applications.

CONTRAM (CONTinuous TRAffic Assignment Model) is a traffic assignment software dealing with traffic in urban networks. This model considers the movement of platoons of vehicles as single entities. The traffic assignment problem within CONTRAM is based on Wardrop's first principle and is solved through iterations in which platoons of vehicles are removed and reassigned to the network.

SATURN (Simulation and Assignment of Traffic in Urban Road Networks) includes a traffic simulation and assignment model for the analysis of various road-investment schemes over large networks. It also includes a separate function for simulating traffic flows at individual junctions.

Software Selection

Because the power of personal computers and the search for traffic management solutions to transport problems is increasing, traffic modeling has become a widely used tool for facilitating transportation planning and traffic engineering applications that are more and more important in traffic engineering.

Currently, there are many traffic simulation packages that tend to satisfy traffic engineering requirements. These simulation models can evaluate alternative scenarios, test new designs, or conduct safety analysis through the re-creation of traffic accidents. The selection of the appropriate simulation model requires the thorough and concrete consideration of many distinct parameters, such as the flexibility of the model, the ease of data collection, validation, calibration and coding, cost, training requirements, user friendliness of the software, and accuracy of the estimation of measures of performance, as well as expandability and the ability of the model to interact with other software. The importance of each dimension will depend on the nature of the activity, its objective, resources available, and user preferences. In fact, the software selection is fundamental to the success of an undertaken project, and this choice is usually a trade-off between the accuracy and the precision of the model and the development costs, data needs, and time required for execution.

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See Also: Activity-Based Models; Destination Choice Models; Full-Feedback Modeling; Intelligent Transportation Systems; Mode Choice Models; Network Modeling; Spatial Equity Analysis; Telematics; Traffic Simulation; Transportation Impact Analysis; Travel Modeling.

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Transportation Plan Implementation, Monitoring, and Evaluation

Transportation plan implementation, monitoring, and evaluation refers to an extensive process undertaken at the local level that involves gathering a wide range of input directed at specific problems in the region's transportation system, most often urban areas with populations over 50,000. Determining where to deploy federal monies targeted for surface transportation planning is central.

Establishing a clear protocol for maintaining transportation systems has three interrelated functions: (1) to set priorities and to define specific goals (as well as workable alternatives) to address those problems based on massive amounts of data gathered and analyzed by state, county, and local transportation planners as well by federal agencies and local transit authorities; (2) to determine how to allocate available federal monies to sponsor the projects and, in turn, devise practical schedules for implementation, and (3) to set standards to evaluate

the projects, to monitor the progress on approved programs, and to measure their effectiveness as a way to guarantee the region's continued mobility.

Transportation planning, because of its largely localized concerns, dispenses with the visionary and the idealistic to deal with immediate problems in a meaningful and organized way and to set clear and specific goals and take into account costs and funding.

Evolution in Transportation Planning

Transportation plan implementation has evolved into significantly more than a simple urban transportation wish list, a kind of to-do list of wide-scope projects that involve either highway development or rehabilitation or transit policy and improvement. Transportation planning now assumes the voice of a wide community interested in linking transportation system performance to long-term strategies for developing not only efficient and reliable transit systems but also to implement those systems as part of a much more comprehensive statement of the relationship between a community and its environment.

Transportation plan implementation is a way to shape not just the needs of a mobile society, a way to move both people and goods efficiently and safely about and around a metropolitan area, but to give that area a vision of its relationship to the land itself, how it will use and conserve land and resources, support growth, shape economic opportunity, and provide a strategy for the future. It is shaped by a meaningful collaboration of diverse perspectives from both the public and private sectors in order to draw up a plan for financing transportation system improvement, ways to maintain and evaluate that system, and make it ultimately part of real economic, social, cultural, and political community growth.

In the decades immediately after World War II, as automobile usage dominated American transportation planning, the process of transportation plan implementation was dominated by traffic engineers and civil engineers. They addressed concerns for maintaining urban and rural roadway capacities, as automobile mobility was seen as crucial to both regional and national economic viability to accommodate the new needs of a suburban workscape. For more than a generation, transportation planning used complicated mathematical

formulas to determine traffic patterns and their sustainability.

Planning was therefore dominated by concerns over destination analysis, congestion reduction, transportation mode preference, route selection, and trip distribution (the number of trips going from one destination to another). The assumption was simple: the future belonged to the automobile and to strategies that provided ways to move people efficiently, safely, and in the largest possible capacities.

By targeting specific traffic problems and extrapolating predictions of future problems, transportation planners worked to create automobile-friendly metropolitan areas. The urban landscape for decades was essentially redesigned with the automobile in mind, with strategies to maintain and minimize congestion, contain and direct volume traffic, and ensure the safety of drivers, all geared to increase mobility and system capacity. In turn, transportation plans initiated a sharp spike in construction—highways, streets, county roads—as the key to transportation efficiency. Evaluation was hardly a priority—spurred by vested interests in the automobile industry, hundreds of miles of highways were built, and there was evident need for more. It was, in retrospect, a very limited perception.

Beginning in the early 1980s, the single-minded agenda was found deficient as concerns emerged over the relationship between urban transportation systems and the environment that sustains it. With the passage in 1977 of the Clean Air Act Amendments, air quality and transportation systems were linked and cities began to examine both stationary and mobile sources of air pollution to set realistic reduction targets with clear planning horizons, usually three to six years. As hard data began to suggest the surface transportation system was having long-term effects on air, water, and noise pollution, transportation plan implementation began to consider more than simply increasing the efficiency and capacity of cars.

Urban planners recognized that transportation planning needed a broader, more encompassing vision that would take into account social, economic, and environmental concerns, and that a variety of other transportation system alternatives including buses, railways, subways, and even bicycles and pedestrian transit needed to be incorporated.

The key was integration—strategies to integrate transportation systems with the environment, current transportation needs with future needs, and ways to integrate transportation systems with community needs broader than simply efficient traffic flow. In turn, transportation planning has become multidisciplinary, including not merely politicians, lobbyists, and engineers but also environmentalists, economists, educators, medical professionals, entrepreneurs, utilities experts, computer software engineers, and climatologists.

Although the goal is still an improved transportation system, it now encompasses emission standards, water quality, enhancing economic opportunities, improving the quality of life in neighborhoods, and encouraging responsible mobility through public education initiatives (a concept that itself includes a wide range of options including using more fuel-efficient cars). Among the strategies under consideration are conserving the number of trips; sharing rides along well-used transport corridors and main arteries leading into the city; constructing priority lanes for high-occupancy vehicles that provide higher speed limits and avoid traffic jams in other lanes; prioritizing transportation options for buses and restructuring bus routes to maximize rider appeal; reducing the speed of vehicles, particularly in residential streets; providing perimeter public parking for commuters willing to use public transportation into the city; encouraging the construction of bike lanes and even redesigning urban streets to prohibit vehicular traffic altogether; promoting city transit systems by expanded schedules, improved stop facilities, and timely service; and encouraging businesses to experiment with flextime schedules to minimize traffic during peak hours.

In short, transportation planning now emphasizes complex and multilayered system management rather than simple system expansion.

Transportation Implementation: Goals and Process

Because transportation planners now recognize how broad and how deep is the impact of a city's transportation system—influencing environmental well-being, cultural and social development, financial and economic viability, neighborhood rehabilitation, tourism, even the aesthetic and visual impact of the cityscape itself—implementation has begun to consider strategies to use transportation

systems to improve the livability of the communities they service. But that can be a difficult goal, easier to state in visionary (and quixotic) rhetoric than to actually achieve. However, transportation plan implementation aims to do just that.

The process works through a series of linked steps. The process begins with a centralized metropolitan planning organization (MPO), a proactive think tank/public policy board. Since the mid-1970s, urban centers of more than 50,000 are required to have a commission whose responsibility is to provide an effective and public setting to make public transportation policy—a board made up of local and state transportation agency representatives as well as transit system operators and whose meetings and operations are matters of public record.

The MPO monitors existing transportation systems and provides a forum for the exchange of information about concerns and/or project proposals for the metropolitan area. In that capacity, the MPO looks at a variety of issues involving transportation systems and environmental health, a process that involves the participation of the public, as spending federal monies is the core responsibility. Although the process is necessarily flexible and addresses concerns endemic to the metropolitan areas served, generally the MPOs work toward seven broad goals:

- In cooperation with demographers, drawing up comprehensive probability statistics on population and business growth
- In cooperation with environmental engineers and a host of technical support staff, assessing and projecting land use and resource availability as it relates to potential transportation system development
- Identifying current and potentially long-term problems and needs that are directly related to the efficiency and capacity operation of surface transportation systems with input from business interests, public advocacy and community interest groups, environmental organizations, freight operators, airport authorities, private transportation providers (such as taxicab services), port authorities, rail executives, public transit representatives, and (especially) the general public who depend on transportation systems
- Developing a specific list of both long-term and short-range initiatives that would provide both the essential capital improvement necessary to alleviate transportation problems or at least minimize their impact and preserve the area's environmental viability
- Providing specific and concrete information on the impact of potential/proposed projects the problems and needs originally identified
- In cooperation with federal agencies and individual state department of transportation and both county and city financial networks, developing real-time cost-effective strategies for financing the project
- Providing a specific agenda for monitoring projects and evaluating their short- and long-term impact as a way to guarantee a timely and meaningful process\

Transportation planning implementation involves specific documents that state and regional transportation planning agencies prepare and make available to the public. These documents provide the ongoing narrative for transportation planning, monitoring, and evaluation, and in turn provide a public record of state and regional planning efforts to develop both an efficient and cost-effective surface transportation system. These documents attempt to provide a coordinated general pool of information about projects under consideration and projects under way:

The Unified Planning Work Program, commissioned every year, is a public archive that keeps a record of all ongoing regional transportation studies, often with specific attention to clean air quality standards, the emissions budget, and those projects already vetted and now in the data-gathering stage as a way to provide a clear vision of the general direction of long-range assessment transportation planning.

The Metropolitan Long-Range Regional Transportation Plans, commissioned every five years, covers at least a 20-year period. This document, usually multivolume, provides a record of those transportation projects currently in process and/or approved along with supporting materials, technical, environmental, and economic, that define both the problems and the goals of the projects.

The Transportation Improvement Plan, commissioned every four years, is an archive that provides a record of the short-term projects actually undertaken from the Regional Transportation Plan and provides a record of the allocation of federal funds.

The State Planning and Research Program is a summary of the research activities and project tasks and an identification of funding sources and the agency commissioning the research.

The Statewide Long-Range Transportation Plan, the plan with the broadest project horizon (up to 20 years), records the long-term projects that involve not only additional construction projects but also ways to maintain and preserve long-term use of existing surface transportation routes. It includes car-centric systems as well as transit programs and nonmotorized systems as a way to direct and coordinate long-term transportation system viability.

Although critics of the cumbersome bureaucracy involved in transportation planning implementation are quick to point out the redundancies in these mandated records and the enormous amount of paperwork and time consumed in preparing them (not to mention the public money required to maintain the superstructure of committees necessary to generate the paperwork), advocates of the system point to the research data and the public record as a way to maintain transparency, and the frequency of documentation as a way to maintain projects' focus and to ensure attention to critical issues in both surface transportation accessibility and efficiency, as well to achieve crucial environmental standards.

At the core of all transportation planning implementation, of course, is not the public archiving of research data or project recommendations but rather the dispensation of federal funding as a way to realize short-term projects with long-term benefits. The goal of all transportation plans is the actual implementation. Although projects are funded by and through an often bewildering entanglement of resource pools (funding for transportation projects can come from state monies, special allotments at the local level, public and private toll systems for users, and local general assessment funds, such as property taxes or sales taxes), the primary

component of transportation implementation is federal funding made available through the federal Highway Trust Fund.

Those funds are given to the state Department of Transportation that, in turn, oversees the reimbursement of local projects—monies from the federal government are not up front. Traditionally, funding from the federal government was strictly separated between highway projects and transit system projects; over the last generation, however, recognizing the increasingly interdependent nature of metropolitan transportation systems and to provide local transportation authorities the chance to respond to conditions and emergencies as needed, the federal government has initiated so-called flexible funding in which local MPOs can actually move the available federal funds freely between transit projects and highway projects according to needs assessments, emergency response conditions, and priority projects.

Issues in Transportation Plan Implementation, Monitoring, and Evaluation

To give some idea of the breadth of issues transportation implementation plans consider is to realize that, although first consideration is given to relatively localized needs and arterial transportation efficiency for the immediate service area, transportation implementation across the country considers several shared issues:

Air quality: The tie between surface transportation systems as well as stationary sources and the quantity of air pollutants ensures that the transportation system emissions rates do not exceed the area's federally mandated emissions budget. Areas that fail to meet that standard, termed non-attainment zones, require priority attention, as federal funding provisions hinge on meeting clean air standards.

Congestion management: MPOs, recognizing the need for efficient operations and open arterial flow in transportation systems, identify regularly congested areas (and those specially designated intersections around major sporting facilities, large-scale shopping venues, business centers, concert/entertainment sites, and university areas prone to regular traffic spikes) and propose alternative roadways, lane redistribution or construction, high occupancy

vehicle (HOV) programs, ramp redesign, the installation or removal of traffic lights, emergency vehicle deployment strategies, and weather contingency operations.

Freight movement: Although enormous public attention is paid to the challenge of moving private vehicular traffic through urban areas, on any given day transportation board data estimates that such private vehicular traffic accounts for less than 40 percent of the arterial flow in a metropolitan transportation system.

Because so much of the local and regional economy depends on the access to and use of highway systems (and streets) by trucks ranging in size and weight loads, lobbyists for the trucking industry regularly petition MPOs on a range of issues involving truck lanes, efficient operations of weigh stations, fuel and truck plaza availability, speed limit ranges, ramp layout and safety, congestion management, traffic light installations and control, as well as emergency assistance programs, all of which influence transportation plan implementation.

Safety and security: For decades, urban management planners have been concerned over emergency vehicle availability, usage, and routing as well as locating and addressing potentially hazardous interchanges or road systems and providing effective speed limits and mandating safety-first driving habits (including wearing seat belts but also restricting driver distractions such as handheld cell phone use and texting).

Broad concerns in transportation planning include not only the safe transport of potentially hazardous materials through a metropolitan transportation system but also concerns raised in the last decade over the targeting of public transit for terrorist attacks, the use of public highway systems for transportation of such weaponry, and the use of public transportation systems for first responders in the event of a widespread emergency.

Technology application: Over the last generation, computer software engineers have become key elements in transportation plan implementation and monitoring, introducing cutting-edge applications able to provide immediate real-time data on traffic flow and to provide drivers with accurate

information on problem areas; maintain better data on air quality; monitor weather conditions; improve efficiency in traffic control by law enforcement; upgrade trucking and freight monitoring; and improve operations at both ports and airports. Because technology is the new frontier in transportation plan implementation, urban planners recognize the potential in computer assistance to better maintain traffic patterns, monitor land and air usage, catalog fuel supplies, route emergency response teams, and enhance safety operations in all phases of urban transportation systems.

Environmental justice: The responsibility of the MPO planning process is to ensure that the maintenance and improvement of transportation services are fairly distributed among a metropolitan area's diverse socioeconomic communities without regard to economic status, ethnic makeup, or gender and age; to ensure that traffic difficulties and health concerns do not disproportionately impact lower-income neighborhoods; and to guarantee all segments of a city's population are given fair access to the planning process and input in the approval—or rejection—of projects.

Although the process of transportation plan implementation and the subsequent monitoring of its effectiveness and the evaluation of its sustainable impact can seem bewildering and overly bureaucratic, the urban planning system provides a clear, collaborative, and transparent process to address transportation concerns and reasonable and timely protocol for real-time improvement.

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See Also: Federal Transportation Policy; Regional Transportation Planning; State Transportation Planning; Transit Planning, International; Transportation Planning; Transportation Planning and Politics.

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Transportation Planning

“Transportation planning” is a broad term that has many meanings. To some, it might mean fixing the potholes in the neighborhood streets. To others, it might mean trying to solve the massive congestion characteristic of most urban areas. To others still, the term might conjure up futuristic transportation vessels as were depicted in the movie *Blade Runner*, or even in the 1960s cartoon *The Jetsons*. In truth, the multidisciplinary field of transportation planning covers all of these areas and more.

Transportation planning is the functional area within transportation engineering that deals with the relationship of land use to travel patterns and travel demands; and the planning, evaluation, and programming of transportation facilities, including roadways, transit, terminals, parking, pedestrian facilities, bikeways, and goods movement.

Transportation planning plays a fundamental role in the state’s, region’s, or community’s vision for its future. It includes a comprehensive consideration of possible strategies; an evaluation process that encompasses diverse viewpoints; the collaborative participation of relevant transportation-related agencies and organizations; and open, timely, and meaningful public involvement.

Because transportation issues are frequently cross-jurisdictional, covering multiple cities, towns, counties, states, and sometimes even countries, most transportation planning is spearheaded by a regional planning organization, also known as a metropolitan planning organization (MPO). However, because MPOs are only mandated in areas with a population of 50,000 or more, in rural areas of the country, most planning is undertaken by state departments of transportation (DOTs).

Transportation planning is not only cross-jurisdictional; it is also cross-disciplinary. While there

are many professionals who work solely as transportation planners, transportation planning is a cross-disciplinary field, performed by a multitude of professionals, including not only planners but also engineers, landscape architects, environmental scientists, and economists, to name just a few.

Evolution of U.S. Transportation Planning

Urban transportation planning in the United States has generally always been conducted by state and local agencies. This is appropriate because most highway and transit facilities and services are owned and operated largely by the states and local agencies. The role of the federal government has traditionally been to set national policy, provide financial aid, supply technical assistance and training, and conduct research.

Over the years, the federal government has attached conditions to the financial assistance it provides. From a planning perspective, the most important has been the requirement that transportation projects in urbanized areas of 50,000 or more population be based on an urban transportation planning process. This requirement was first incorporated into the Federal-Aid Highway Act of 1962.

The Federal-Aid Highway Act of 1962 was the first piece of federal legislation to mandate urban transportation planning as a condition for receiving federal funds in urbanized areas. It asserted that federal concern in urban transportation was to be integrated with land development and provided a major stimulus to urban transportation planning.

Two features of the act were particularly significant with respect to the organizational arrangements for carrying out the planning process. First, it called for a planning process in urban areas rather than cities, which moved the scale to the metropolitan or regional level. Second, it called for the process to be carried on cooperatively by the states and local communities.

Because qualified planning agencies to take on such a transportation planning process were lacking in many urban areas, the Bureau of Public Roads (BPR) required the creation of planning agencies or organizational arrangements that would be capable of carrying out the required planning process. The growing momentum of the highway program, coupled with the cooperative financing of the planning process by the Housing and Home Finance Administration (HHFA) and the BPR, helped lead to the

formation of numerous regional planning agencies around the country.

U.S. Department of Transportation

Other legislation that helped grow the transportation planning industry followed. In 1966, the U.S. Department of Transportation (USDOT) was established. Its mission was to coordinate transportation programs and to facilitate the development and improvement of coordinated transportation services utilizing private enterprise to the maximum extent feasible. The Federal Aid Highway Act of 1968 established the Traffic Operations Program to Improve Capacity and Safety (TOPICS). The program was designed to reduce traffic congestion and facilitate the flow of traffic in urban areas.

The Federal Aid Highway Act of 1970 established the federal-aid urban highway system. The system in each urban area was to be designed to serve major centers of activity and to serve local goals and objectives. Routes on the system were to be selected by local officials and state departments cooperatively. This provision significantly increased the influence of local jurisdictions in urban highway decisions.

The Federal Aid Highway Act of 1973 contained two provisions that increased flexibility in the use of highway funds for urban mass transportation. First, federal aid urban system funds were to be used for capital expenditures on urban mass transportation projects. Second, funds from the Highway Trust Fund (HTF) could be diverted to mass transportation projects.

Therefore, the 1973 Federal Aid Highway Act took a significant step toward integrating and balancing the country's highway and mass transportation programs. It also increased the role of local officials in the selection of urban highway projects and broadened the scope of transportation planning by MPOs, which were to be designated by the states to perform this planning function.

1980s and 1990s

With five titles and 149 sections, the Surface Transportation and Uniform Relocation Assistance Act of 1987 (STURAA) was passed by Congress on April 2, 1987. The STURAA authorized \$87.6 billion for the five-year period from fiscal year 1987 to fiscal year 1991 for the federal aid highway, safety,

and mass transportations programs. It also updated the rules for compensating persons and businesses displaced by federal development and extended the HTF through June 30, 1994.

The 1980s brought a new challenge to urban transportation planning—the decentralization of authority and responsibility. The national mood had shifted, and centralized approaches were no longer considered to be the appropriate means for dealing with national problems. The federal government started to reduce its involvement, which left the states and local governments with more flexibility to fashion their planning procedures and institutions to their own local problems and needs. More time and effort could be used to produce information for local decisions rather than to meet federal requirements. The federal statutes remained in force, but additional federal guidance or elaboration was reduced and eliminated.

On the other hand, however, planning had to be more responsive to the needs of local decision makers and citizens, and to adjust to the realities of long-term budget constraints in many urban areas. The urban transportation planning processes had been attuned to federal requirements and had to realign procedures and institutional arrangements to address local issues and needs.

Many of the issues that were debated in the 1970s were revisited in the 1990s. One issue was the appropriate balance between long-range and short-term planning. A second was the level of effort devoted to system expansion, infrastructure rehabilitation, system management, and possibly even system retrenchment (for example, removal of certain facilities or routes) to match declining population, travel demand, and financial resources.

The issues of changing institutional arrangements and locus of decision making were being raised in a number of urban areas. Many urban areas are attempting to use transportation to foster economic development while still providing mobility. The use of innovative financing techniques such as special improvement districts (SIDs), business improvement districts (BIDs), and public-private partnerships (PPPs) have increased to offset shortfalls in public-sector funds.

Environmental quality, transportation for special groups (that is, the poor, the disabled, and the elderly), and sustainability began to take on greater significance across the spectrum of urban



Park-and-ride stations like this one in Denver, Colorado, offer people the option of leaving their vehicles close to home and transferring to a bus, rail system, or carpool for the remainder of their journey. The location of these park-and-ride stations is critical to their success. They must be conveniently located in the suburbs of metropolitan areas or on the outer edges of large cities in order to attract commuters.

areas and broadened the transportation planning field considerably.

The Transportation Planning Process

Transportation planning is a cooperative, collaborative, and continuous process designed to foster involvement by all users of the system, such as the business community, community groups, environmental organizations, the traveling public, freight operators, and the general public. In the United States, most transportation planning is led by the MPO, in consultation with the federal and state DOTs, transit operators, and the federal and state environmental agencies.

Transportation planning includes a number of steps. The first is to establish a regional vision and goals. Many communities have extensive visioning exercises, which usually involve extensive public outreach. The visioning process is used to lay out goals, which are more specific statements identifying what a community wants to achieve. While goals

can vary from plan to plan or region to region, they are usually general. Examples of goals are “Improve Transportation Safety” or “Rebuild and Maintain the Region’s Transportation Infrastructure.”

The next step, development of alternate improvement strategies, consists of identifying current and projected future transportation problems and needs and analyzing, through detailed planning studies, various transportation improvement strategies to address those needs. The strategies can be operational, such as traffic signal synchronization; capital improvements, such as widening a roadway; or system management, as in incentivizing the implementation of carpooling and vanpooling programs.

In most cases, the transportation system’s needs far outweigh the financial resources available to implement these strategies, and so transportation planners must next evaluate and prioritize strategies. They do this utilizing a wide range of tools, including cost-benefit analysis, and specialized programs known as asset management systems, which

help decision makers to identify and prioritize capital expenditures when resources (funding and personnel) are limited.

In addition to evaluating the financial resources required to implement strategies and projects, planners and engineers use specialized tools and models to determine the impacts of various strategies on system attributes such as traffic congestion, air quality, and traffic safety. All of these tools aid planners in determining which projects and strategies should move forward.

The hallmark of any transportation planning process is the long-range (sometimes known as regional or metropolitan) transportation plan (LRP). This plan covers a horizon of at least 20 years and identifies specific programs, strategies, and projects that will help a community or a region achieve its transportation goals.

Under federal law, all transportation projects receiving federal funding must come from a long-range plan. In addition to specific projects and strategies, long-range plans assess future travel demand via future population and employment forecasts, as well as identify major growth corridors that are likely to need major transportation improvements.

In some plans, land uses are projected as well. Under the Federal Planning Rule, all long-range plans must also include a financial plan to show that there will be sufficient revenues to cover the costs of implementing all these proposed projects. Many plans also include “aspirational” projects, which function more as a “wish list” of projects that are desired but for which there is no identified funding source.

The development of a transportation improvement program is the step of the transportation planning process where funds actually are programmed and committed to a project. The programmed funding and detailed list of projects are published in a Transportation Improvement Program (TIP), usually covering four years but updated more frequently. As with the long-range plan described above, for any project to receive federal funds, it must be in the TIP.

Transportation planning also involves project development, which is the process that takes a project from concept through construction. Project development is initiated in response to an identified need in the transportation system. As described above, the need might include one

or more of the following: a congestion problem, a safety concern, pavement or bridge deterioration, an environmental enhancement, or even an economic improvement opportunity. It covers a range of activities, beginning with identification of a need to a finished set of contract plans, completion of all environmental documents required, and construction.

An integral part of the transportation planning process is implementation of strategies and projects as programmed in the TIP and long-range plan. In many areas, transportation planners are removed from the implementation process. However, this is changing as fiscal constraints and an increased emphasis on expediting project delivery are forcing transportation planners and system operators to integrate their roles and responsibilities. This is especially noticeable in the congestion management process, in which planners may initially identify congested locations and problem areas and suggest potential strategies to mitigate the problem, but still need the expertise of operations officials to assess the feasibility of implementing these strategies.

Once projects are implemented, a transportation planner’s job is not over. A major part of the transportation planning process is monitoring the recently implemented strategies and projects to see how the system is performing and whether the goals outlined in the long-range plan are being met. Indeed, the recent federal legislation known as MAP-21 (Moving Ahead for Progress in the 21st Century), has put increased emphasis on measuring system performance and on comparing performance metrics against specific targets to which state DOTs will have to adhere if they want to continue receiving federal transportation funds.

Components of Transportation Planning

Even within the transportation planning field, the following different components of transportation planning exist.

- *Traffic operations:* The analysis, review, and application of traffic data systems to the operation of transportation facilities
- *Traffic design:* The determination of travel patterns and parking characteristics of transportation users in the planning and design of transportation facilities

- *Traffic research:* The conduct of theoretical and applied research to understand and develop new applications of technology that improve mobility, enhance the environment, and conserve energy resources

Transportation Authorization Legislation

Notwithstanding the legislation described earlier that helped give rise to the transportation planning industry, there has been a series of transportation reauthorizations in the past several years that have greatly enhanced the role of transportation planners in authorizing and allocating federal funds for transportation improvement projects. They are summarized in Table 1.

The current transportation authorization bill, MAP-21, funds transportation from fiscal year 2012 to fiscal year 2014 at \$105 billion each year. As mentioned above, there is a much greater emphasis on performance measures and targets, to which state DOTs and, by extension MPOs, must adhere.

This is the first step toward creating a true performance-based budgeting process for prioritizing how the United States invests in transportation. This approach is intended to provide taxpayers with the best return on their investment, while also improving livability and promoting global competitiveness.

The law also creates new regional transportation planning organizations, which allow for greater involvement of nonmetropolitan areas in planning. Further, the bill consolidates a lot of existing programs and delegates more authority to the states in making transportation planning decisions.

Challenges

Not surprisingly, the greatest challenge facing transportation planners is highly constrained financial resources, which are hindering the ability

of planners and engineers to make the needed improvements to America's transportation system. America's roads received a grade of "D" in the American Society of Civil Engineers' (ASCE) recent report card, which determined the need for \$170 billion in annual investment, almost 90 percent more than the current actual roadway investment of \$91 billion.

Further, transportation planning must be conducted in a highly politicized environment, which makes getting projects done very difficult. More and more, politicians focus on short-term measures that will help their election prospects rather than long-term investments, such as infrastructure.

Nothing is more politically unpalatable than raising taxes, probably the most common method for raising revenue for transportation projects. There is a large difference between what transportation professionals think should be spent and what Congress and state and local governments are willing to spend. Because much transportation planning is done on the regional level, and MPOs represent a multitude of city and county governments, it is difficult to attain consensus on major projects, especially in this era of fiscal constraint.

Many areas in the United States operate under "home rule," meaning that all power to regulate land use and zoning lies within each municipality. Because transportation planning, predominantly governed at the regional level, is intertwined with land use, which is governed at the local level, it is difficult for large, multi-jurisdictional projects, which often require changes in land use, to get done.

The Future of Transportation Planning

The level of detail and complexity of planning procedures is being reassessed. Smaller urban areas are opting for a simpler planning process that is

Table 1 Federal transportation reauthorizations, 1991 to 2012

Year Signed Into Law	Title of Bill
1991	Intermodal Surface Transportation Efficiency Act (ISTEA)
1998	Transportation Equity Act for the 21st Century (TEA-21)
2005	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)
2012	Moving Ahead for Progress in the 21st Century (MAP-21)

Source: David S. Heller.

commensurate with their fewer problems and less complex planning context. The larger areas have many more problems to address, options to evaluate, and organizational arrangements and procedures to use.

Greater emphasis in transportation planning is being placed on both the corridor- and site-level scale of planning, as opposed to the regional scale. As discussed above, there is growing awareness on the part of all planning practitioners that land use planning has to be integrated with transportation planning for it to be effective. Given the severely limited financial resources experienced by all levels of government, most of the future planning, at least in the near term, will be on system preservation and maintenance rather than new construction. A major contributing factor to the lack of funding is the diminishing value of the federal gas tax, which is the main source of revenue for the HTE, the chief source of funding for highway projects.

At 18.4 cents a gallon, the gas tax has not been raised since 1993. Meanwhile, the cost of highway construction and repair has increased 55 percent over the past 20 years. That means drivers today are chipping in the same \$3 in federal taxes per tank of gas that they paid in 1993, even as the construction projects being funded with that \$3 have become much more expensive. This has led to a deep shortfall in the HTE.

The Congressional Budget Office (CBO) projects that by 2015, the HTE will have insufficient revenues to meet its obligations, resulting in steadily accumulating shortfalls. According to a CBO report issued in 2013, federal lawmakers would have to cut transportation spending by more than 92 percent or increase the gas tax by more than 50 percent to bring revenue in line with transportation spending. Indexing the gas tax to inflation would put transportation revenue on a much more sustainable path. Had it been indexed to inflation, the gas tax would be about 29 cents today.

Some people have proposed a tax on the number of miles driven, known as a vehicle-miles traveled (VMT) tax, as a way to increase highway revenue. Vehicles would be charged a per mile fee, with heavier vehicles that cause more wear and tear on the road being assessed a slightly higher fee. Possible methods of enforcement could be the electronic toll collection, already common on many freeways and expressways, and for local roads, an

odometer reading associated with annual vehicle registration renewal.

Even though Congress passed a transportation reauthorization bill in the summer of 2012 with MAP-21, it spans only two years, hardly enough time for states and regions to make long-term capital spending plans, particularly when transportation projects can span multiple years. Further, with federal assistance declining and the trend expected to continue at least in the near term, most of the burden for funding infrastructure will fall to state and local government entities, which are as—if not more—strapped than the federal government. It is likely that some important construction will be deferred.

With rising costs and the uncertainty about how future projects will be funded, policy makers are looking for effective alternatives for both funding new and maintaining current, transportation infrastructure. In many areas around the country, businesses have joined together to create public-private partnerships (PPPs), contractual agreements formed between a public agency and a private-sector entity that allow for greater private-sector participation in the delivery of transportation projects.

PPP projects often are undertaken to supplement conventional procurement practices as a way to achieve cost and time efficiencies and expand funding sources, thereby reducing demands on constrained public budgets. While practices among different PPPs may vary, members of the PPP propose to pool financial and construction-related resources to build and finance projects. In transportation projects, PPPs have been used across the country because of their effectiveness and ability to reduce costs and construction times.

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See Also: Federal Aid Highway Program; Intermodal Surface Transportation Efficiency Act; Metropolitan Planning Organizations; Moving Ahead for Progress in the 21st Century Act; Regional Transportation Plans; Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users; Transportation Improvement Programs.

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Transportation Planning and Politics

Transportation planning refers to the processes through which a vast array of measures and activities are undertaken that combine to manage the transportation network. Transportation politics refers to the decision making and dialogue that occurs to determine which transport infrastructure gets built or refurbished, which new investments

get prioritized, and how funding for transportation is allocated and spent. These processes differ in contexts across the world, and while there may be similar norms across cities, regions and countries in the world, there is no one overarching standard.

By their very nature, then, transportation planning and politics are often complex processes that are difficult to understand because of the number of stakeholders involved and the relationships between them. Delivery of transport projects is often conducted by third parties and public-private partnerships are increasingly popular. On the whole, responsibility for transportation planning is separated by mode and across and between levels of government.

Certain interactions that occur can be described as hierarchical, but there have been calls for more networked and participatory planning, development, and delivery of transportation because of increased awareness of the need to consider social and environmental factors of transport, as well as only economic considerations as has traditionally been the case. There is a large bureaucracy surrounding the planning and politics of transportation, and, as such, it is difficult to offer a complete picture of the processes that occur as a whole. Much has been written on road and city-based planning and will be the primary focus here.

Traditional Transportation Planning

While there are no common norms through which transportation planning occurs across the world, with local and regional variations commonplace, certain generalizations can be made about the similarities that exist in the way transportation planning occurred in most Western economies for the greater part of the 20th century. Road infrastructure is planned for, managed, and maintained by a host of parties.

Land use policy and local roads have generally been the purview of local authorities; regional/state roads are managed by regional or state authorities; and highways, freeways, interstates, and motorways are generally handled by a national/federal government. With regard to public transport, bus and light rail transit are typically run through a mixture of local, regional, and national companies—often in partnership with one another, which makes the management and maintenance of routes, fleets, and service a complex system to manage.

Freight transport and passenger transport have different needs and often find themselves in competition for resources, including space on the network. Transportation planning often considers the needs of passenger or freight transport in isolation, which can perpetuate these incompatibilities. With regard to rail, in certain countries, passenger and freight rail is nationalized in others, such as the United Kingdom, it has become privatized, leading to differing types of rolling stock and introducing competition for routes and a fragmentation in terms of services and providers.

Planning for walking and cycling infrastructure is generally managed by local authorities but has not been considered historically in major road projects, especially in the United States. Therefore, the provision of nonmotorized transport has until recent years been limited, and remains so to a large extent. Many transportation departments would not consider walking and cycling within their responsibilities, and there is often a disconnect within transportation departments between large-scale infrastructure investments and projects and “softer” people-oriented projects, such as pedestrian planning. As will be discussed, the call for more integrated transport, which has become more pronounced over the last 20 years, has led to more planning of projects that have a multimodal character.

With the post–World War II introduction of more commercial airline use and, more recently, the advent of low-cost airlines, air travel routes and airport capacity is managed separately. In shipping, too, both passenger and freight ships are planned for and managed separately. With increasing calls for integration across modes and for modal shift away from air to rail, or car to public transit, it is likely that in the future there will be a need for much closer and considered planning across modes, but at the present time, this separation of interests is a dominant feature of how transportation planning operates on the whole.

The primary foundation for road-based planning and decision making for several decades was the “predict and provide” tenet. An extremely significant investment was made starting in the 1950s in developing highway infrastructure, along with predicting where people would drive and how much, through running sophisticated transport models; this became the chief measure for planning transport projects to cope with demand. The primary

emphasis on delivery of projects has been economic in terms of providing transport infrastructure through the least-cost option, but also with consideration for maximizing the economic output that could be derived from a particular infrastructural investment over a given time period.

When road congestion became an increasing problem, the dominant solution was to plan and build increased road capacity to keep up with escalating demand. Since the 1980s, the approach of building more roads as a way out of the problem has been called into question, not only because such transportation planning predominantly focuses on those with access to private vehicles—and further marginalizes those without access—but also because increasing capacity has failed on the whole to deal with the rising demand and congestion. Additional capacity has actually induced further demand.

Expansion and Efficiency

One of the primary principles of the predict-and-provide approach was expansion, and transportation professionals over the past 70 years or so have been rewarded for successfully planning and implementing expansion projects. Similarly, conventional transportation planning would conceive of efficiency as a flow-of-traffic consideration (that is, a transport system would be understood to be more efficient if the vehicle speeds were increased).

This conception is clearly incompatible with the use of the term *efficiency* as referring to the need for more fuel-efficient vehicles and systems; these have been considered a priority for transportation planning, as well as for politicians, because of increasing environmental and health concerns among the public that have been highlighted over recent decades.

Indeed, the very nature of what is expected of transportation planning and politics is becoming very different from the conventional ways in which policies have been developed and transport systems produced during the 20th century. A broader array of stakeholders are participating in and contributing to the policy and planning processes in a manner that has not always been the case.

Politics and Pork Barrel Projects

It is fair to say that extremely strong influence is exerted over transportation planning and politics by industry lobbies that have been developed over decades to protect and promote business interests.

The intrinsic link between transportation and economic growth makes the relationship between transportation and business a very involved and complex one. Restricting transport flows and mobility is perceived as equivalent to restricting fiscal prosperity, and one of the significant and fundamental challenges faced by the transportation sector is how to decouple growth from transport demand. This, by definition, means that business has a strong voice in planning future transportation activity across all modes.

The automobile industry and the oil-and-gas sector lobby are just two of the most vocal and powerful examples of the commercial interests that exert significant influence over the transport decision and implementation processes. Businesses protect their own corporate interests and strive to make sure that government investment occurs and money gets spent on transport projects that meet or serve their particular interests.

One example of this complicated relationship is demonstrated by so-called pork barrel politics, which refers to financial investments being made to serve the interests of particular politicians or voters in return for their support through votes or monetary contributions.

Such tactics, while often difficult to prove because of the opaque decision-making processes that deliver transportation projects, highlight the increasingly complex interrelations between local, metropolitan, regional, and federal policy makers, and businesses and politicians. The “Big Dig” in Boston, Massachusetts, and the “Bridge to Nowhere” in Alaska are recent examples of transportation projects accused of being funded through pork barrel politics.

There are also certain high-profile examples where the dominance exerted by business has had significant, long-term impacts on the transportation landscape. This phenomenon is not new. In 1949, for example, several companies involved in the acquisition and subsequent removal of streetcar and electric train systems in American cities were convicted of conspiring to monopolize interstate commerce. Some commentators claim that such deliberate attempts to destroy transit systems in many cities was a key contributor to the automobile dependence witnessed across the United States since the 1950s.

The importance of gaining consensus from an increasing number of stakeholders in the delivery



Planning for biking or walking trails like this one at Wave Hill in the Bronx in New York City are typically managed by local authorities. Many transportation planning departments do not consider walking paths a part of their responsibility.

of transportation projects should not be underestimated. Just as the social and environmental impacts of transportation have been highlighted in the past few decades, so, too, has attention been drawn to the closed decision-making processes through which transportation investments and policies are made.

The power and influence of the corporate lobby should not be underestimated because it is one of the primary barriers to delivering alternate, sustainable transportation infrastructures. However, there are indications that the shift required to diminish business' disproportionate influence over transportation planning regimes and practices—and to make the system more accountable and democratic—has begun.

Participatory Planning Processes

As increasing calls are made for environmental and social considerations to be integrated into

transportation planning and policy implementation, transportation planners, policy makers, and politicians are being asked to fundamentally alter the way in which their decisions are made. This means that project successes can no longer be judged on the size of expansion, the cost of a development, or how fast traffic will accelerate.

Transportation planning increasingly needs to introduce a broader array of modes—walking, cycling, transit—into any development, and it needs to offer up space currently dedicated to the car to alternatives. Planning also needs to consider efficiency in terms of the least environmentally impactful way to get around and to consult with different communities and social entities, as well as businesses, to ensure that well-being and quality of life are considered alongside the bottom line.

Decision-making processes must become more transparent, and there needs to be consensus, or at least dialogue, between previously disparate groups of society in order to ensure that transportation planners do not keep trying to build their way out of gridlock, but instead try to provide sufficient infrastructure for alternative modes and to encourage their use.

There is a need for denser communities and to reduce the number of vehicle miles traveled. This presents a huge challenge for transportation planners, but it also emphasizes the need for planning to be holistic. Land use planners and transportation planners need to work more closely together to create long-term visions for communities that are integrated, connected, and resilient to environmental changes.

There is a need to think more broadly; transportation should be connected better with housing, health, planning, environment, energy, industry, and other policy areas. Most policy in these areas has been made in isolation and has resulted in a very fragmented, energy-intensive, inefficient, and unequal landscape in transportation and society.

Greater public participation is required across departments and across different levels of government to develop processes to redress the lack of balance that comes from primarily economically focused decision making, and to begin to move toward a more robust, longer-term perspective that runs independently of election cycles.

The entrenched shortcomings of the current transportation planning system are being

perpetuated with every funding cycle that invests in new roads to promote economic development. Multimodal transport can address health, transport, business, and housing issues, but not without an adequate amount of attention from politicians over a longer time horizon.

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See Also: Federal Transportation Policy; Fiscal Politics; Globalization; State Transportation Planning; Sustainable Transportation; Transportation Impacts on Land Use; Transportation Planning.

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Transportation Policies, African

Transportation is considered a backbone of development, especially for the African continent. However, from a transportation perspective, the region would be perceived as not having enough road networks as well as lacking transportation policies. The lack of roads, especially rural roads, is viewed as a major physical constraint on mitigating poverty in the continent.

Africa is a continent with diverse culture composed of numerous countries. As diverse as the population is, the transport systems of Africa also exhibit a significant contrast in coverage and efficiency. For example, in 2011, the country of Chad had only 128 miles (206 kilometers [km]) of paved urban roads, while Tunisia, South Africa, Namibia, and Botswana each boasted over 3,107 miles (5,000 km) of paved urban roads.

Sub-Saharan Africa has a much lower density of paved roads than any other region in the world. It has only 127 miles (204 km) of roads per 386 square miles (1,000 square km [km²]) of land area, with only one-quarter paved. This compares with a world average of 587 miles (944 km) of roads per 386 square miles (1,000 km²) of land area, with over one-half paved.

The spatial density of roads in sub-Saharan Africa is less than 30 percent of the next-worst-provided region, South Asia, with one-half being paved, and only 6 percent of North Africa, with two-thirds paved. Traveling from one African country to another sometimes requires transiting through a European city by air. Apart from the problem of an inadequate and ill-maintained transport infrastructure, the continent is burdened with institutional hurdles, including cumbersome administrative and custom, procedures, corrupt officials and staff, lack of transportation policy, and a list of other deficiencies.

However, there are recent improvements in the transportation sector. Cities of some countries in Africa are exhibiting remarkable overall economic growth and this is reflected in the transportation sector. For example, in Addis Ababa, the capital of Ethiopia, the city's performance in the transportation sector has been so remarkable that the total road length grew from 845 miles (1,360 km) in 1998 to 1,983 miles (3,192 km) in 2010—that is, 135 percent growth in a period of 12 years.

Also, in the southern part of Africa, each country has been taking initiatives to rehabilitate, upgrade, and maintain existing road networks, as well as to construct new roads. For example, in Lesotho, the road network is constantly being expanded and upgraded, especially with the Lesotho Highlands Water Project, as development of the road network begins to access the more remote areas. In Madagascar, reforms and rehabilitation are taking place through the Transport Sector Program. In

Mozambique, the Roads and Coastal Shipping Program led by the World Bank has made developing the internal transport system a priority.

There are still several challenges for Africa's transportation industry. Although the major problem is lack of transportation policy that guides development, there are also poor institutional frameworks and lack of technical and financial resources.

On the technical side, serious problems of early cracking in bituminous pavements are frequent, especially in sub-Saharan countries, as well as rutting of paved surfaces not long after their construction. The explanation of these phenomena may sometimes be found in the choice of a weak road structure and sometimes in poor workmanship. Related to this, corruption of some African officials and technicians plays a role as well.

Civil unrest and border wars have caused disruption in the progress of road network improvement. Conflicts and wars in many countries have ruined the efforts carried out in the transportation sector.

Since their independence, almost all 43 sub-Saharan countries have been involved in civil wars or wars with other countries, and they have suffered from serious problems of internal disorder. The prolonged civil wars in some countries resulted in significant damage to road and rail networks, and the effects continue to be felt despite current initiatives to rebuild the networks.

Brief History

Africa's modern transportation infrastructure evolved during periods of colonial influence that focused on the development of transportation that facilitated links with Europe, other colonial holdings (for example, India), and trade routes within Africa that served colonial purposes. As a result, Africa is characterized by limited internal linkages, with only major cities designated as international gateways (seaports) to serve foreign markets.

Colonial authorities paid little or no attention to road building. For instance, in the case of French West Africa, there were hardly any roads outside a few urban areas in the region in 1914. The colonial powers invested almost exclusively in railways, which brought them economic benefits by transverseing the vast expanses between their designated places of commerce. Their need to minimize cost led them to build only those roads and streets that were absolutely necessary for colonial governance.

Because colonial powers recognized the importance of their physical presence throughout the colonies as a critical element of control, they proceeded to build a limited number of roads linking some hinterland areas to the colonial government centers. In the area of air transportation, very few airports were developed in Africa during the colonial era, and their purpose was primarily to link the colonies to “master” nations. Little, if any, efforts were made to link African cities by air.

Even several decades after independence, the transportation infrastructure of African countries didn’t show a sign of remarkable growth for many years, and there was no single transportation policy to guide the development of transportation infrastructure.

There are a number of reasons for sluggish growth in Africa, including poor economic and political performance, topographic conditions, and administrative incompetence. However, in recent years, with the help of the global financial institutions and the involvement of China, many African countries are exhibiting a remarkable growth in the transportation industry.

Sub-Saharan Africa Transport Policy Program

If there is one program that defines Africa’s (especially sub-Saharan Africa’s) transportation policy, it is the Sub-Saharan Africa Transport Program (SSATP). Originally called Sub-Saharan Africa Transport Policy Program, the organization started with a small group of African and international engineers and policy makers who were deeply concerned with the poor condition of the region’s road network.

Funding had long been a problem. Despite some nations having invested billions of dollars in road network funds, these nations were running out of money, and by the early 1980s, only 20 percent of the classified road networks were in excellent condition. Another conundrum for poor nations in the region was that they could not afford even the refurbishment of their existing networks, let alone help fund the construction of an extensive road network of the entire region.

Unfortunately, countries with deteriorating road networks would economically decline and poverty would increase. To address these challenges, Sub-Saharan Africa Transport Policy Program founders devised policies, such as institutional arrangements and capacity building, to stop the unproductive

cycle of road building, collapsing, and rebuilding for African countries.

In 1986, the founding group members met at the United Nations Economic Commission for Africa (UNECA) to develop a program that would address the neglect of the region’s road networks. The 1987 inaugural meeting in Oslo, Norway, led to the creation of the International Advisory Committee (IAC), which was a joint committee of the World Bank and UNECA. Offices were located in Addis Ababa, Ethiopia. However, program operations stalled as a result of funding limitations until 1988, when the organization relocated to the World Bank’s offices in Washington, D.C., and renamed itself the Sub-Saharan Africa Transport Program.

In its early days, the SSATP addressed a wide spectrum of issues, such as road maintenance, railway management, low-volume roads, rural travel and transport, development of agriculture and transport, taxation in transport, and many other issues. The program attracted several agencies from African countries and some international agencies. These stakeholders in a short time limited the range of the program to focus on policy issues.

By 1992, the program was implemented through seven components: Road Maintenance Initiative (RMI), Rural Travel and Transport Program (RTTP), Urban Mobility (UM), Trade and Transport (T&T), Railway Restructuring (RR), Human Resources and Institutional Development (HRID), and Transport Data (TD). RMI is meant to facilitate policy reforms resulting in sustainable maintenance and financing of public roads. RTTP is designed to better the livelihood of rural people by improving access to basic goods and services.

UM’s goal is to support and facilitate the provision of safe, efficient, and less polluting transport in cities of sub-Saharan Africa. T&T is designed to reinforce the international competitiveness of sub-Saharan African economies. RR is to help countries establish efficient and financially sustainable railway enterprises. HRID focuses on capacity building for policy reforms. Finally, TD is to provide information systems to support policy preparation.

The founding nine member countries, supported by small groups of donors, requested the UNECA and the World Bank to continue serving as executing agencies through the seven components. Membership grew from nine to 17 member countries in the 1990s.

The RMI component was the main attraction to the SSATP because its goal was to bring roads to the marketplace. Toward the end of the 1990s, African countries felt the SSATP was too donor-oriented, leading to funds being earmarked for specific projects that were geared toward donors' interests.

With fluctuating finances and weakening leadership in SSATP, African countries felt increasingly marginalized. Donors were also frustrated with the lack of management reporting, and they did not sufficiently recognize the program's policy principles aimed at poverty reduction. The concerns of African countries and donors were confirmed in the 1999 management review, and all parties concluded that there needed to be an improvement in the management framework of the program.

UNECA and donors gathered in 2000 to conduct a detailed analysis of the program. Conclusions of the seminal meeting changed the program, resulting in a new mission statement, a new governance framework, the setting up of an executive board, the formation of a ministerial advisory group, and the recruitment of a full-time program manager. In 2001, further review was conducted on five African countries impacted by the program, and recommendations were made for more African involvement in program management.

These recommendations led to the implementation of national and African regional coordinators based in Africa. Hence, SSATP became a stronger partnership with a sounder governance structure. By 2003, 30 African countries were engaged in different components of the program, and donor confidence was restored. The RMI and RTTP were the most popular of all the components. By 2006, the number of members increased to 35.

The governance framework of the SSATP is designed to govern management and program operations. The executive board acts as the program's guardian, moneymaker, and publicist, with members representing stakeholder constituencies.

The Constituent Assembly, which is a collection of donors, selects and guides the primary management team. The team is facilitated by the World Bank in offices located in Washington, D.C.; Nairobi, Kenya, and Yaoundé, Cameroon. Also, the team is supported by a network of SSATP coordinators in every member country.

Finances are channeled to a multidonor trust fund managed by the World Bank. The SSATP

annually holds a stakeholder meeting to review progress, discuss best practices, be advised by the ministerial advisory team, and support dialogue regarding policy progress and its effects.

From a coordination approach, the program's framework is to introduce programs at a country level, endorse SSATP policies and practices for dialogue regarding national policy, and to carry out program activities. The national coordinator leads the process and is able to request assistance from experienced individuals from other sectors for logical advice on policy and strategy. This type of coordination framework hinges on governmental backing and involvement in a sector-wide dialogue concerning all stakeholders.

Since the program's implementation, especially in the last decade, SSATP reports that countries have economically improved. Ten of the 48 sub-Saharan African countries have had economic growth in excess of 5 percent each year since 2005. There is no doubt that improved transport has contributed significantly to Africa's growth.

The social landscape has improved with many more people having access to health centers and more children able to go to school. The SSATP has a distinguished history of supporting information gathering, analysis, and dissemination. This has led to development of principles, themes, and areas of focus that have had a substantial impact on individual countries' transport policy formulation and implementation.

Some of the impact is being seen with the recent program resurgence and widening influence on the policies and operations of countries, regional economic organizations, aid agencies, and international organizations, such as the World Bank, UNECA, and the European community. On an overall program level, the SSATP is focusing efforts on national transport policies and programs that support poverty reduction strategies—specifically, on clarifying the role of transport in achieving the goals of other sectors, such as health, education, and agriculture.

The influence of the principles and themes championed by SSATP on transport-sector development has been strong and consistent. For instance, the influence can be clearly seen in Ethiopia, where an agriculture-led development plan triggered a comprehensive road sector development program (RSDP), which enjoys the support of many donors.

The RMI principles—ownership, stable financing, responsibility, and good management, all supporting the theme of commercialization—have been central to the Ethiopian RSDP. Similar principles championed by the RTTP, such as ownership, good management, and adequate funding, have been applied not only to policy, but also to actual or pending improvements in many country programs that enjoy wide support.

Transportation Policy in Northern Africa

North African countries include Algeria, Egypt, Libya, Morocco, Sudan, Tunisia, and the Moroccan territory of Western Sahara. Literature on transportation policies of north Africa is usually meshed with the Middle East because of cultural and social resemblance. With few exceptions, the region's cities don't have well-organized transport systems, and have suffered from a lack of transportation policy while transport demand is constantly increasing.

Recognizing the problems and their negative impact on the economy and society, national governments and local authorities in nearly all the north African countries have now embarked on far-reaching structural reforms regarding the building of major infrastructure projects. Based on the amount of information available, this section will briefly discuss on transportation in Algeria, Egypt, and Morocco, based on UITP (International Association of Public Transport) reports.

In Algeria, each of the 48 provinces contains a transportation department for urban transportation and land transportation. Shortly after independence (1962), Algeria had a well-developed transport network, especially with the merging of the rail systems Tramways Algeriens (TA) and Chemins de Fer Sur Routes d'Algerie (CFRA), now known as L'Entreprise Publique de Transport Urbain et Suburbain d'Alger (ETUSA, Algiers Public Transport Company).

Algiers's first urban transport map of the regional and urban company network CFRA dates back to 1908. Until 1987, urban transport services were almost entirely provided by public operators that generally came under the control of local authorities. The deregulation of the sector was immediately followed by the proliferation of private operators and an overall increase in supply (doubling of the number of minibuses and taxis, with more than 22, 000 taxis for the six main cities,

half of which operate in Algiers). This led to a drop in the market share for public operators who had lost their monopoly.

In the capital of Algiers, over the past few years, a major urban infrastructure construction and refurbishment program has been instituted by the provinces of Algiers. Moreover, the Algerian government has launched an ambitious five-year development plan. Accordingly, the Ministry of Transport prepared a public urban transport plan and a master traffic plan designed to resolve the problems concerning the transport sector in Algiers and to meet the traveling needs of the population.

In Morocco, the Ministry of Home Affairs is in charge of transportation at the national level. The Economic and Social Division manages it for the ministry at the city level through various public corporations or contracts awarded to private carriers. Through these channels, Morocco is addressing the segments of the region's cities that have suffered from a lack of transport policy, despite the fact that transport demand is constantly increasing.

Research indicates that the country has agencies and departments for urban transportation that govern the transportation system, but effective transportation policy is still required. After understanding the problems and their impacts on the economy and society, the Moroccan government and local authorities have now started to implement structural reforms and to build major infrastructure projects.

In Egypt, the four main urban locations are Greater Cairo, Alexandria, Port Said, and Suez. Urban public transport systems exist in these areas and in the main cities and administrative capitals. Transport networks in Egypt can be divided into intercity networks and urban networks. The intercity networks include rail networks, highway networks, and inland waterway routes along the Nile River and its branches. Urban networks include local roads, subway (Metro) networks, urban railway lines, and some routes for ferryboat services. Passenger services in Egypt can be divided into two categories: regulated services provided or monitored by the Ministry of Transport, and services provided by private operators (not planned or regulated by the Ministry of Transport).

Cairo Master Plan

According to the Ministry of Transport, the Greater Cairo Region (GCR) , as the main urban region of Egypt, will experience increasing transport

problems in the future. Because of this recognition, the Strategic Urban Development Master Plan of the Greater Cairo Region (a policy and planning document) in 2008 identified many projects that needed to be implemented, including new infrastructure projects and redevelopment projects.

The master plan identified many actions, policies, and projects that need special attention, such as minimizing usage of private cars, giving attention to parking problems, and developing new systems for increasing parking lots. The master plan also included actions such as promoting park-and-ride, implementing traffic management solutions, applying bus priority lanes and segregated lane systems, especially along the newly planned corridors, and developing ring roads around the main cities and communities.

Among the focuses of the master plan were incentives and governmental support for private-sector involvement in public transport services, with coordination and integration with the existing modes; development of a vehicle inspection system for assuring safety and environmentally friendly trips; development of comprehensive planning for both urban and rural areas; promotion of demand management rather than increasing transport supply; and limiting the role of the government in organizing and regulating the transport business.

Conclusion

Sub-Saharan transportation is mainly shaped by the Sub-Saharan Africa Transport Policy Program (SSATP). There has been a 30 percent improvement in the number of roads classified as good under SSATP management, but government corruption, civil unrest, and poor workmanship still hinders progress. SSATP is criticized for a lack of African leadership and management. This was somewhat corrected through framework restructuring in mid-2000, which yielded greater donor confidence.

One other point to note is that transportation was excluded from (or barely mentioned in) the United Nations' Millennium Development Goals (MDGs). The MDGs, initiated in 2000 to alleviate poverty, do not encompass targets to lessen the transport constraints on the poor. This is a concern for many because Africa, more than any other continent, is known for its vast, sparsely populated rural areas, lack of transport infrastructure, and rural poverty.

The relative immobility of sub-Saharan African rural dwellers and their poor access to social and productive services and markets is especially pronounced. North African countries are just beginning to have a transportation policy that guides urban transportation growth and development.

For the last decade, an increase in urban populations and their accompanying transportation problems have prompted several countries to come up with transportation master plans and implementations are now under way.

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See Also: Transportation Policies, Asian; Transportation Policies, European; Transportation Policies, North American; Transportation Policies, South and Central American.

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Transportation Policies, Asian

The nature of transport problems varies among world regions. Asian countries in particular face severe problems of congestion, maintenance, upgrading facilities, and degradation of the environment due to high levels of noise and air pollution. For instance, India, with over a billion people in 2011, of whom more than 30 percent reside in urban areas, faces transport problems such as accessibility to jobs, businesses, and education and recreation centers.

The government of India implemented a National Urban Transport Policy in 2006 with the objectives of encouraging integrated land use and transport planning in all metropolitan cities, improving access of business to markets, introducing intelligent transport systems for traffic management, reducing pollution levels via changes in traveling behavior, and promoting greater use of cleaner technologies.

The Indian government also enunciated a transport development project of completing a "Golden Quadrilateral" highway network connecting India's four largest cities—Delhi, Mumbai, Kolkata, and Chennai—thereby forming the four vertices of a quadrilateral. The program was announced in 2001 at an estimated cost of \$11 billion by the National Highways Authority of India, under the Ministry of Roads, Transport and Highways. Four other metropolitan cities—namely, Bengaluru, Pune, Ahmedabad, and Surat—will also be served by this network; thus the agricultural, industrial, and cultural centers of India will be connected.

This network development plan will provide several benefits such as improved accessibility to major cities and ports; easy movement of people, freight, and products; industrial and job development in smaller towns and cities; provision to farmers of market access for their exports; indirect demand for cement, steel, and building materials for real estate development; and, finally, the impetus for truck transport.

Most Asian countries face severe problems of congestion, and therefore government and transport planning agencies adopt transport demand management (TDM) measures. In China the rapid growth of the economy during the past three

decades has led to urbanization and motorization, in turn exacerbating problems of traffic congestion, urban sprawl, energy consumption, and rising air pollution. Policy analysts argued for an increased supply of public transportation, although during the 1990s and 2000s the response was an increased supply of roads. This was expected to mitigate the problems of urban mobility, accessibility, and congestion.

For example, in Shanghai the proportion of expenditures on public transportation increased to more than 80 percent during 2010, while the rest of the country increased the share by 6 percent during 2003 and 2009. There has also been an enhanced focus on construction of high-speed rail to ease the movement of people and thus increase connectivity.

There still remain several problems such as lack of integration of high-speed rail with the bus system in cities and lack of coordination between metro rail and bus systems because multiple agencies manage the two systems. Policy makers need to implement policies deterring the usage and ownership of private cars by raising parking fees and adopting bid-auction mechanisms for vehicle registration.

For instance, Singapore implemented a bidding system for vehicle purchasing rights and electronic road pricing policies for restricting automobile dependency and, thereby, reducing private vehicles on roads. Until the 1990s, policy makers in Singapore utilized fiscal restraints on car ownership, such as import taxes, registration fees, and an additional registration fee which is equivalent to a percentage of the import price of the car. However, during the 1980s the government provided discounts on the sale of old and used cars older than 10 years old in the scrap market, thereby driving the prices of used cars above their original value.

This development rendered car ownership and usage policies less effective. In turn, it displeased the public since the speculative car traders made windfall gains at the expense of the larger public. A lesson for future car ownership policy making is to be wary of the potential of creating speculative asset markets for cars that might generate social inequity.

Similarly, in the Seoul metropolitan area in South Korea, the congestion problem is severe; the government tried supplying more transport roads to ease the congestion problem but to no effect. The problem has been very severe in the Namsan



Rickshaws, hand carts, tuk-tuks, motorcycles, and cars all vie for the right-of-way in New Delhi traffic. Concern about increasing traffic congestion and its environmental and health consequences has been an important research agenda in the past decade. Recently, there has been a growing realization that based on current policies, transport trends are not sustainable.

tunnels, which connect the city with the central business district. During the mid-1990s, the Seoul metropolitan government implemented toll fees on private cars with fewer than two persons. This increased bus and subway use and increased the average vehicle speed in the downtown area.

In sum, a combination of transport demand management such as toll fees, parking fees, expensive car registration, gasoline taxes, and higher taxes and fees for car ownership can perhaps mitigate road congestion, thereby alleviating environmental problems as well.

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See Also: Transportation Planning and Politics;
Transportation Policies, African; Transportation Policies,

European; Transportation Policies, North American;
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Transportation Policies, European

The objective of a Common Transport Policy (CTP) for Europe can be traced back to the Treaty of Rome, which was signed in 1957 and established the European Economic Community (EEC). Transport was one of main areas of common policy of the treaty, but some of the ideas behind a common transport policy for Europe can be traced back even further in time. In 1951, for example, the Treaty of Paris established the European Coal and Steel Community (the forerunner of the EEC) and contained a chapter on transport.

Despite being a common area of policy for more than 50 years and featuring in all key European treaties, transport policy developed relatively slowly, especially up to the mid-1980s, which is generally considered to be a turning point in European transport policy making. Before this time, many member states were unwilling to relinquish control of national transport markets and had very different views about the role of transport policy vis-à-vis the economy and society. Both the policy focus and the level of activity in policy making were quite different between these two periods (1950s to mid-1980s and mid-1980s to present).

Transportation Policy 1950s to 1980s

The first phase of community initiatives, from the late 1950s until the mid-1980s, was primarily aimed at establishing common standards, harmonizing member states' regulations on transport, and establishing common conditions for transport services. In the 1960s, a detailed transport policy program was developed, but this soon proved unacceptable to many member states that ascribed to a range of political ideologies. For some member states, the proposals were considered too liberal; for others, the proposals were judged to be incompatible with their situations.

In spite of the high ambitions of many leaders, attempts to create an overarching common transport policy in the 1960s were blocked at every turn. By the early 1970s, as a consequence of these experiences, the European Commission switched to a more pragmatic approach to transport policy, where many transport-related issues were pursued separately in order to find solutions in specific areas

and specific modes. Consequently, progress on the development of a common transport policy for Europe was slow and piecemeal.

In 1974, the scope of the CTP was broadened by the European Court of Justice, which ruled that while the specific provisions establishing the CTP applied only to inland modes, aviation and maritime transport were nevertheless subject to the general provisions of the European treaty. However, it was not until a decade later that policies in these areas were developed.

Slow progress in the development of a European CTP up to the mid-1980s was primarily a result of the inability to reconcile the opposing interests and regulatory approaches of the member states under the condition of unanimous voting in the European Council. At the outset, the CTP was hampered by contrasting regulatory approaches and conflicting economic interests of the member states.

Half of the six founding members of the EEC—France, Germany, and Italy—had national policy regimes characterized by a high degree of state intervention in transport markets, and so they were traditionally skeptical of a liberal transport regime at the European level. Those countries viewed transport policy as a means to accomplish regional, industrial, and social policy goals. The Netherlands, in contrast, was a pronounced supporter of a liberal approach to European transport policy, having seen benefits for Dutch transport industries under a more deregulated system.

Another explanation for slow progress in the development of the CTP is that, because various international bodies and agreements on transport already existed, the development of a European CTP was not always regarded as absolutely necessary. In 1983, the European Parliament, which had generally supported the European Commission's efforts to develop the CTP, took the Council of Ministers to the European Court of Justice for "failing to introduce a common policy for transport and in particular to lay down the framework of such a policy in a binding manner," as required by the Treaty of Rome.

In a landmark ruling in 1985, the European Court judged that the Council had indeed "failed to ensure freedom to provide services in the sphere of international transport and to lay down the conditions under which nonresident carriers may operate transport services in a Member State," and was therefore

in breach of the treaty. This effectively marked a watershed moment for European transport policy.

In addition to the “inactivity verdict” from the European Court of Justice, other political factors helped contribute to a subsequent acceleration of policy making on the CTP. One of the most important other developments was the publication of the *White Paper on Completing the Single Market*, which contained around 300 legislative measures to be taken, many of which had implications for transport. The white paper argued that

the right to provide transport services freely throughout the Community is an important part of the Common Transport Policy set out in the Treaty . . . and that the development of a free market in this sector would have considerable economic consequences for industry and trade.

Thus, the evolution of the CTP in the mid-1980s was a consequence of a combination of institutional developments supporting the acceleration of the policy-making process and a change in the political ideology in some member states.

European transport policy was incorporated into efforts to achieve the internal market, and was seen as a precondition for an effective market because it would provide links between producers, markets, and consumers. These developments, taken together, amounted to a major transfer of transport policy powers from nation-states to Europe.

The foundations of contemporary common transport policy were laid between 1985 and 1992 under the impetus of the single market program. The late 1980s and early 1990s saw the introduction of a raft of measures as the European Single Market was established. Policies shifted from standardization (harmonization) to liberalization, and a number of transport sectors were targeted for deregulation (for example, shipping, air transport, rail, road haulage). In addition, European funding was granted for a number of new transport infrastructure projects from the late 1980s onward via the Structural Funds, especially the European Regional Development Fund, which became more available to transport projects after reforms in 1988.

The mid-1980s also heralded the first appearance of European environmental policy, which had important implications for transport policy. The



Eurostar trains, shown at Waterloo International railway station, run through the Channel Tunnel between the United Kingdom and France and Belgium. Most Eurostars can carry 750 passengers, which is roughly equivalent to five Boeing 737s.

1986 Single European Act contained new articles on the environment, and the 1992 Treaty on the European Union (the Maastricht Treaty) further underlined the position of environmental policy in relation to transport policies (and other sectors).

At the same time, the issues of transport safety and transport infrastructure were given more prominence in the 1992 treaty, thereby extending the scope of a common transport policy for Europe. One of the centerpieces of the new transport policy agenda was the development of pan-European transport infrastructure, the Trans-European Transport Network (TEN-T).

Trans-European Transport Network

One of the main ideas behind developing the TEN-T was to underpin and strengthen the creation of Europe's internal market and to reinforce economic and social cohesion. The objective was to integrate national networks and modes of transport, link peripheral regions of the European Union to the center, and improve safety and efficiency.

While the policy foundations for the TEN-T are contained in the 1992 Maastricht Treaty, the idea of a common infrastructure policy for Europe was not entirely new. Since the early 1980s, calls for a trans-European network were being made by the European Round Table of Industrialists (ERT), one of the most powerful business groups in Europe, representing some of Europe's largest automobile and oil companies.

One analyst called the ERT the "spiritual progenitor" of the TEN-T, and the beginnings of the policy can be traced to a 1984 ERT report titled "Missing Links," which proposed three major European transport infrastructure projects: (1) EuroRoute, an English Channel link between England and France; (2) Scanlink, a plan to fill in the road and rail gaps between Norway, Sweden, Denmark, and northern Germany; and (3) a trans-European network of high-speed trains.

Having defined infrastructure problems in terms of missing international infrastructure links, the ERT then sought to set the agenda for action and, in 1991, called for a better network of roads (especially to overcome Alpine and Pyrenean mountain barriers), high-speed railways, and air terminals in a report titled "Missing Networks—A European Challenge." The ERT's 1991 report formed a blueprint for the TEN-T proposals introduced in the 1992 Transport White Paper, published just a few months later.

The formal decision to develop the TEN-T was made by the European Parliament and Council in 1996. Since then, the plans for the network have undergone several revisions as a result of the expansion of the European Union and budgetary changes. The guidelines for the development of the trans-European transport network, adopted in 1996, provide the general reference framework for the implementation of the transport network and for identifying projects of common interest.

A list of 14 major infrastructure projects (the "Essen projects") was included in the 1996 guidelines as the first priorities to be completed before 2010. In 2001, the TEN-T guidelines were amended in various respects, including greater emphasis on the multimodal dimension of the TEN-T, by bringing seaports and inland ports fully into the network.

The guidelines were amended again in 2004, primarily in order to take account of EU enlargement and the expected changes in traffic flows. The 2004 guidelines included a list of 30 priority projects of

European interest: the original 14 Essen projects plus an additional 16 projects to be completed by 2020. More than half of these 30 projects concerned rail transport (17 projects), another four concerned road transport, four were multimodal in nature, three concerned water transport, one concerned an air transport project, and one was a global navigation and positioning project (Galileo).

In 2005, the TEN-T was presented as a key element for increasing economic competitiveness and employment. Since 2006, the Trans-European Transport Network Executive Agency (TEN-T EA) has had the responsibility for implementing and managing the TEN-T program on behalf of the European Commission.

In general, TEN-T projects are funded to a major extent by national governments, but they also receive funding through various European community financial instruments (for example, Cohesion Fund in eligible countries and European Regional Development Fund), as well as loans from the European Investment Bank.

Although the majority of the priority projects concerned rail and the fact that more than half of the TEN-T special budget line went toward rail, European financial support for TEN-T projects is nevertheless skewed toward road transport, particularly under the more sizable Cohesion Fund and EDRF budgets. Consequently, the TEN-T policy has aroused opposition on environmental grounds with critics saying it merely promotes road use at the expense of parallel modes (rail) and undercuts sustainability objectives.

TEN-T policy has also been controversial because of relatively low economic impacts and high environmental impacts, particularly when it comes to biodiversity associated with the development of infrastructure along some parts of the network. The policy also has been criticized because it does not provide an effective contribution to the EU's climate change objectives, and because it increases the demand for transport by adding new routes and increasing the speed of travel.

Although presented as a strategic, integrated, pan-European policy, TEN-T essentially represents a loose collection of nationally or regionally important infrastructure projects. According to the European Commission's own 2009 review of the TEN-T policy, the planning of the network "has not been driven by genuine European objectives."

Others have argued that the EU's role in transportation policy has been mainly limited to acting as a catalyst to the process by identifying the common European interest of projects, and operating as a facilitator in negotiations between European states and subnational governments as well as private-public partnerships, construction companies, and service operators.

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See Also: Transportation Planning and Politics; Transportation Policies, African; Transportation Policies, Asian; Transportation Policies, North American; Transportation Policies, South and Central American.

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Transportation Policies, North American

In the United States, transportation policy is carried out by the U.S. Department of Transportation (USDOT), created in 1967; transport had previously been a function of the Department of Commerce.

The Department of Transportation includes a number of federal agencies that formulate policy and regulations for different areas of transportation in the United States: the Federal Aviation Administration, the Federal Highway Administration, the Federal Motor Carrier Safety Administration, the Federal Railroad Administration, the U.S. Maritime Administration, the National Highway Traffic Safety Administration, the Pipeline and Hazardous Materials Safety Administration, the Research and Innovative Technology Administration, the Saint Lawrence Seaway Development Corporation, and the Surface Transportation Board. Until 2003 when the Department of Homeland Security assumed them, the Transportation Security Administration and U.S. Coast Guard were also part of the USDOT.

Standards, protocols, and guidelines for use in highway design and construction are set by the American Association of State Highway and Transportation Officials (AASHTO), which has operated since 1914 and has a membership that includes the DOTs of every state, as well as Puerto Rico and Washington, D.C. AASHTO also provides some of the data used in formulating transportation policy and is the primary source of data on road structural design and materials reference.

The Transportation Research Board (TRB) advises the federal government, including federal

agencies, the USDOT, Congress and congressional committees, and the president, on scientific and technical matters related to transportation policy. It is one of the six major divisions of the National Research Council, a scientific advisory body administered by the Institute of Medicine, the National Academy of Sciences, and the National Academy of Engineering.

The TRB's annual meeting brings together over 10,000 transportation researchers and professionals, and throughout the year research is pursued by more than 200 task forces and committee groups. One of the TRB's programs is the National Cooperative Highway Research Program, established in 1962 to promote the research of solutions to highway problems, including efficiency, maintenance and repair, engineering and construction, and safety and security. The program draws on the funding of state transportation departments, each of which is expected to contribute 5.5 percent of their research funds.

Canadian Transport Policy

In Canada, transportation policy is developed by Transport Canada and the Canadian Transportation Agency. Transport Canada, established in 1935, develops Canadian transportation services and the regulations and policies that govern them, including the Canadian Coast Guard, the Railway Safety Act, the Marine Transportation Security Act, and the Transportation of Dangerous Goods Act. It also oversees motor vehicle safety in accordance with the 1971 Motor Vehicle Safety Act, and accessibility for people with disabilities to railroads and other services.

Transport Canada also has jurisdiction over Canadian waterways and civil aviation, and operates the nation's publicly owned airports. As in the United States, transportation infrastructure has been generally underfunded in recent decades, in part because of growing conservative factions seeking to limit government spending and in part because of the emergence of new forms of infrastructure that have attracted funding at transportation's expense, notably high-speed telecommunications and Internet infrastructure.

The Canadian Transportation Agency is a tribunal given decision-making power in certain areas related to transportation policy. It is responsible for the licensing related to federally regulated

transportation, ensuring that national transportation systems are accessible to people with disabilities and others, and resolving complaints about federally regulated transportation.

Transport Policy in Mexico

In Mexico, transportation policy is formed by the legislature, the president, and the Secretariat of Communications and Transportation, the federal agency responsible for commercial transportation regulation (as well as regulating broadcasting). Regulation of civil aviation falls to the Directorate General of Civil Aeronautics, which is principally concerned with aviation safety.

Mexico City, one of the largest cities in the world, with unique transportation and infrastructure challenges, was awarded the 2013 Sustainable Transport Award by the Institute for Transportation and Development Policy (ITDP), an American non-governmental organization that provides assistance and advocacy for sustainable transportation in the Americas, Asia, and Africa.

The ITDP helped develop Mexico City's Bicycle Master Plan program, which gave the highly populated city a vast network of bicycle paths designed for connectivity to other transportation modes in order to encourage bicycle use for practical, everyday purposes, rather than just recreation. The Bicycle Master Plan was one of many recent additions to Mexico City's transportation policy. Metrobus, the citywide transit system, was expanded with new lines, while Ecobici, the city's public bicycle system, was expanded significantly after an initial pilot period.

Street parking regulations were also reformed, and new traffic management policies were adopted in order to attempt to calm traffic for greater safety. The ITDP also assisted Mexico City in revitalizing the city's Historic Center, including building a bus line from the Historic Center to the airport, improving street maintenance, instituting new parking management systems, and reorienting the area toward bicycle and pedestrian traffic and public transportation.

The city has undertaken a long-term plan to attempt to reduce vehicle emissions, having for a long time suffered some of the world's worst vehicle-related air pollution. The growth of the Mexican middle class has resulted in skyrocketing automobile ownership in a country with few regulations

about greenhouse gases or vehicle emissions. In 2011, for instance, despite the worldwide financial crisis, the total number of cars in the country increased by 11 percent.

The changes enacted in Mexico City in 2012 helped transform it from one of the worst commuter cities in the world to one of the best, thanks to a greatly improved transportation system, improved public spaces, Ecobici and the Bicycle Master Plan, a new nine-mile subway line called the Golden Line, and various pedestrian-friendly measures. It is the first time that transportation policies have actively encouraged forms of travel other than the automobile.

Improvements to parking management resulted in a reduction in “cruising for parking,” the time spent looking for a parking space in the city, which fell from an average of 13 minutes to three, while emissions fell for the first time in years. Most federal efforts in Mexico still favor motor vehicles, however, with about 84 percent of 2012 federal expenditures on urban mobility spent on motor vehicle infrastructure such as roads, bridges, and parking lots.

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See Also: Transportation Planning and Politics; Transportation Policies, African; Transportation Policies, Asian; Transportation Policies, European; Transportation Policies, South and Central American.

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Transportation Policies, South and Central American

According to the United Nations, approximately 75 percent of the population in South America currently lives in cities, and the urban population is

expected to rise by more than 80 percent by 2020. This urban population is highly dependent on public transport, performing the majority of their daily trips in buses or metros. However, economic growth and greater access to financial credit in the last 20 years in the region has caused the number of vehicles per person to rise from 0.08 to 0.17. In this context, key issues that have motivated transport policies in the region are air pollution, traffic safety, and traffic congestion.

Although transportation policy presents a diverse picture throughout South America, some of the most important measures implemented in the recent past are road space rationing, improving public transport systems, implementing fuel taxes, and expanding the capacity for private automobiles.

Road Space Rationing

The most common transport policy in South America consists of restrictions on the use of cars at certain times and on certain days. This has been implemented since the 1980s in Chile and Mexico, and later in other countries, such as Brazil, Colombia, and Ecuador. Although the key motivation has been air pollution mitigation in the majority of these cases, easing congestion in its own right is also a direct or indirect expected result for policy makers.

The implementation of these policies is diverse. In Bogotá and Medellín, Colombia, and Quito, Ecuador, cars are banned from circulating one weekday at peak hours, whereas in Mexico City cars cannot circulate during any business hours once a week. Similarly, Santiago, Chile’s space rationing program bans cars from circulating in the metropolitan area once a week, but applies only to those cars without a catalytic converter.

Further uses of these programs include extending the ban to motorcycles and raising the number of days that cars cannot circulate, such as in the case of Medellín. Most of these space rationing policies are implemented year-round or, at least, in the colder months of the year, especially if the main motivation is environmental.

However, space rationing has also been implemented as an emergency measure only when air pollution reaches critical levels, as in the case of the state of Rodizio in Brazil. In these situations, banning has sometimes been extended to public transport trucks and higher numbers of cars, such as in Santiago.

Despite the extension of space rationing as a policy throughout South America, the evaluation of its impacts on air pollution and congestion is mixed. In the case of air pollution, some cases showed no evidence of air quality improvements, such as in Mexico City; others suggest important decreases, such as in the case of Quito.

Although several evaluations have shown a decrease in congestion levels, it is not clear to what extent these effects are offset by an increase in car ownership and use and by the rearrangement of daily routines. In addition, assessing these policies is less clear in the light of improvements in clean technology, such as the increasing number of cars with catalytic converters and the improvements in fuel quality. Yet, space rationing is a policy still in place in most of these cities with the dual purpose of improving air quality and congestion.

Public Transport Systems

The majority of public transport systems in the region have high levels of deregulation, resulting from such factors as the free market policies of recent decades, the strong influence of current operators and unions, and the historically passive position of governments at all levels.

As a consequence, public transport systems in the region are predominantly independently operated, with fierce internal competition, which has led to excesses of supply, the lack of integration of services, and negative externalities, such as air pollution, congestion, and accidents. Pressured by those problems, some governments have taken action to improve public transport systems.

Some policies have been directed toward building or expanding current metro systems, and, because of the high investments needed, only few major cities in five countries (Chile, Colombia, Venezuela, Argentina, and Peru) have running metros. The exception is Brazil, whose population size justifies public transport investments in several cities.

Given the scarcity of funds throughout the region, though, most public transport policies have been directed toward improving bus systems in terms of regulation and operations. In fact, successful policies have led to an institutional transition from independent and deregulated markets to public and government-regulated services. Some examples of these policies are Curitiba's master plan in

Brazil; Transmilenio in Bogotá, Colombia; Transantiago in Santiago, Chile; and other related initiatives in Ecuador and Peru.

Curitiba's master plan, developed in 1965, was a pioneer public transport initiative in the region, consisting of a highly connected network of more than 50 miles (80 kilometers) of exclusive bus-lane corridors and several feeder lines, with very high levels of service standards. The plan is aligned with the city's land use planning, which promotes denser use along the corridors. The system is a public-private joint venture; the administration of the system consists of one entity managing the operations and revenue and another central entity handling strategic and long-term decisions.

Following Curitiba's successful experience, Bogotá's Transmilenio system has been gradually implemented since 2000. Transmilenio consists of several trunk lines that run in separated lanes and feeder lines that cover important parts of the city. The system was financed at the municipal and national levels. The program has been successful in professionalizing the services, substantially improving bus speeds and reducing air pollution.

Motivated by these other experiences, Transantiago was implemented in 2007 in Santiago de Chile, following a system of dedicated-lane trunk and feeder buses that integrate the whole city's public transport system. Improvements included contactless smart cards and a financial administration separated from the operators. Transantiago was initially designed so that no subsidies would be needed for the private operators.

In contrast with Transmilenio's implementation, the Transantiago system went from regulated to deregulated overnight. However, at implementation, there were not enough dedicated lanes, which had negative consequences in terms of bus frequencies and travel times. Those issues, in addition to the underestimation of the level of cultural change that the new system involved, negatively impacted transit ridership. After revising the initial design, mainly through government subsidies, and changes in the operations, the system's level of service and ridership has improved, as did air pollution.

Other countries have pursued more limited policies with varied results. Examples of these systems are Metrobus in Mexico City and Metrobus-Q in Quito. New regulatory regimes have been put

in place in Argentina in order to turn independently owned cooperatives into formal commercial enterprises, with mixed results.

In the case of Lima, Peru, the complete deregulation introduced in 1990 led to an increasing number of trips by motorcycle taxi, and a degradation of the system into one of the oldest public transport fleets in the region. High-capacity busways in dedicated rights-of-way and a new central transit authority have arisen in recent years to overcome these issues. In the case of Caracas, Venezuela, the metro is not integrated with the minibus system, but in La Paz, Bolivia, public transport still mainly consists of single minibus owners and passenger operators.

Fuel Taxes

A less common transportation policy is fuel taxes, partly because of the resistance from the general public and partly because of the availability of cheap oil in some countries, such as Venezuela. One of the exceptions is Chile, where the so-called Specific Tax was implemented in 1986 as a way of collecting money after the earthquake that hit the country's central area the year before. The tax is still in place, but with unclear objectives, which range from improving environmental and economic efficiency to collecting money for transport infrastructure. The effect of this policy is hard to measure because there are no explicit transfer mechanisms to ensure that the collected money is indeed used for tackling these goals.

Expanding Capacity to Private Automobiles

The increasing mobility and auto ownership levels, and consequent congestion levels, experienced in several cities in the region have put pressure upon governments not only to improve public transport systems or restrict the use of cars but also to expand capacity for private automobiles. The limited amount of available funds for achieving this goal has encouraged different forms of public-private partnership arrangements.

One example is the implementation of five urban highways in the core area of metropolitan Santiago in the 1990s and 2000s, which were financed through a private-public partnership with public bidding for four interoperable free-flow electronic tolling highways. The level of service for cars improved substantially, although at a high investment cost.

Current Trends and Challenges

Despite these policies, the increasing mobility needs in South America require intensifying and extending the regulation and modernization process for public transport systems throughout the region. In fact, these challenges are becoming important not only in city capitals but also in other cities within each country. The implementation of bus rapid transit in several cities in Colombia and other innovative transit systems, such as the cable cars in Medellín, are some current answers.

Current governance structures in the region are in general very rigid in terms of encouraging policies that could integrate land use, transportation, and environmental dimensions, all within a multimodal perspective. This integrated perspective requires learning from the experiences of some of the projects delineated here, even though they may be contradictory when the provision of infrastructure for cars is weighed against improvement of public transport.

There is still resistance among politicians from the region to implementing other transportation policies that have been implemented in other parts of the world, such as congestion pricing for roads and other travel demand-and-supply management tools.

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See Also: Bus Rapid Transit; Privatization of Public Transit; Transportation Policies, African; Transportation Policies, Asian; Transportation Policies, European; Transportation Policies, North American.

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Transportation Policy, U.S.

Transportation policy in the United States is primarily carried out by state and local agencies, with some input, guidance, or earmarked funding provided by the federal government. The U.S. Department of Transportation (US DOT) and its agencies also set relevant regulations (as do a handful of other federal agencies—the Environmental Protection Agency, for example, regulates some aspects of transportation planning that bear on the emissions in vehicular exhaust).

State-level planning helps better coordinate local development while also addressing issues beyond the purview, or sometimes the interest, of the local government, such as the impact on other communities, the environmental consequences, and social and economic ramifications on a larger than local scale. In short, state-level planning looks at the “big picture.”

It is often suggested that federal-level planning could do likewise, but the federal government’s guiding hand is not often felt, despite the public’s perception that the ratio of federal to state power and involvement is greater than it used to be. A number of issues either fail to be resolved or have unwanted consequences because of state-level thinking without more federal involvement.

For instance, the Greater Boston area encompasses not only the Massachusetts communities surrounding Boston but parts of New Hampshire and Rhode Island, and there has long been a plan to extend “T” service (the Boston-area subway) to southern New Hampshire, both for commuters (of which there are many in the region) and shoppers. Both states agree they will benefit, but disagreements over which state funds how much of each stage of development, land acquisition, and construction have repeatedly stalled the project.

Beyond the Rational Planning Model

Modern transportation planning has historically followed the rational planning model, which consists of a straightforward model for making transportation planning decisions. The rational planning model begins with an overview of the relevant data followed by the identification of the problem to be solved. This is followed by stages that propose

a goal, identify and assign weights to the criteria by which plans will be evaluated, generate various alternatives, create a model of the situation, and determine the optimal decision to reach the defined goal.

The rational planning model is sometimes faulted for assuming that sufficient information about the problem can be obtained and that the consequences of various options can be foreknown. Even apart from this, the process is time-consuming and can be taxing on resources in the information-gathering phase.

In part due to environmentalism, but also due to changes in American thought and in the academic environment in which transportation planners receive their training, the rational planning model no longer has the dominance it once had. Instead, planners, especially younger planners, often have a multidisciplinary background and are as likely to draw on sustainable development models or behavioral psychology or social justice concerns in formulating their plans.

Beginning around the 1960s, transportation planning has increasingly been treated by many as a component of larger plans or a way to promote social, economic, or environmental policies. Transportation plans may actively encourage walking or bicycling, for instance, or the use of car-share services over car ownership, which tends to cut down on unnecessary car usage. The overall trend in transportation planning in the United States, as in the United Kingdom and South Korea, is to expand the scope of planning beyond finding the most affordable and efficient means of addressing a transportation problem toward a planning approach that encompasses and synthesizes multiple goals.

This means, for instance, integrating transportation planning with land use planning, environmental concerns, health concerns, and concerns about access to resources. For instance, modern transportation planners take more specific notice of the effects on the elderly or disabled of possible transportation plans; they are concerned about resource problems afflicting particular populations or neighborhoods, like food deserts and the effects of gentrification; they have for some time now wrestled with the effects of suburban sprawl. In short, they are occupied with planning transportation projects that address the needs of American society, the environment, and the economy.

This is a significant change from an approach that previously was occupied mainly with building new roads and new routes, whereas today, a major project of the transportation planners in, say, Boulder, Colorado, is not to build new roads but to widen and pave the shoulders of existing roads, in order to increase the city's bikeable miles.

The Example of Boulder, Colorado

Boulder worked at increasing the city's bicycle access for over a decade before launching 2011's bike share program, which for a low membership fee makes bicycles available at public stations throughout the city. The bicycles are available for up to one hour with no additional fee beyond the cost of membership; this is to encourage fast turnover and the use of bicycles less for recreational rides around the city and more for the practical trips that would otherwise be made by bus or car.

The Boulder bikeshare program, B-Cycle, is a good example of the concerns of modern transportation planning. The program is expected to generate a profit for the city and has no real economic toll; it takes into account the reasons for travel as well as the means; it encourages a particular means both through incentives (the convenience of using an available bicycle you do not need to store at home) and by making it easier to use (by making the city streets easier to bicycle); its benefits include economic benefits to the citizenry (more Boulder residents can now give up car ownership, or drive less and use less gas, or if already carless have access to opportunities they might not otherwise), health benefits to the bikers (particularly reducing risks of heart disease and diabetes, major health problems facing the country), and environmental benefits by reducing the emissions associated with driving. (It's easy for riders to quantify these benefits, as the software that manages the B-Cycle system uses unique user profiles that monitor burned calories, biked miles, and carbon offset.)

A year after launching, B-Cycle received a federal grant for expansion. In 2013, when Boulder was hit by the 100-year flood that claimed several lives, there was no time to evacuate B-Cycle's equipment. Despite devastating flooding throughout much of Colorado, and several of the bicycle stations being completely submerged, the damage to the bicycles and the equipment used to rent them

to pass-holders was minimal. Within a couple of weeks, 19 of 22 stations and nearly the full fleet of bicycles were back online.

One of the bicycles was painted green (instead of the retro cherry red of the rest of the fleet), and throughout the following month, \$5 was donated to flood relief efforts for every ride logged on the green bicycle.

2009 Economic Stimulus

When the \$787 billion economic stimulus plan was passed in February 2009, nearly \$30 billion of it was allocated to transportation investments. The money was disbursed to state governments and metropolitan planning organizations (MPOs) with little earmarking—transportation projects could be chosen by the states and MPOs as they desired, for the most part. It was well understood that there was a nationwide backlog of bridge and road repairs, even apart from the funding needs of current and future public transportation systems.

Approaches varied considerably. Some states spent most of the money on building new roads rather than repairing existing ones, with one-third of the total money going to new-capacity roadway projects. Because building new roads involves a time-consuming planning and land acquisition process, these projects took longer and created fewer jobs.

Less than 3 percent was spent on public transportation, despite ridership reaching an all-time high and numerous public transportation agencies cutting routes and services because of the recession. Less than 1 percent was spent on bicycle and pedestrian projects, though it is possible that this should be considered in light of their lower cost compared to motorized infrastructure. The distribution of funds was different from state to state, of course. Vermont's "fix it first" transportation policy meant nearly all of the state's money went to repairing or upgrading existing infrastructure, with a small portion spent on public transportation and nothing on new roads.

Arkansas, at the other extreme, spent 81 percent on new roads and other infrastructure and nothing on public transportation, leaving little for repairs, despite the fact that only 38 percent of its roads were rated as being in good condition by the American Association of State Highway and Transportation Officials.

One of the cities to receive a stimulus grant for transportation was the 45,000-resident town of Normal, Illinois, which received \$22 million to build a transportation hub. Normal's hub locates trains, city buses, regional bus services, and taxis in a centralized building as part of a redevelopment effort centered in the uptown area, which was made more accessible for pedestrians, bicyclists, and public transportation. City officials advocated for the next federal transportation reauthorization bill to encourage similar projects for similarly sized cities throughout the country.

Organization

Which agency is responsible for transportation policy and addressing the issues that impact transportation planning varies from jurisdiction to jurisdiction. In particular, local governments vary considerably in size, complexity, and type. Some small communities in New England still make policy and budget decisions through town meetings, for instance, while other communities vote on ballot issues, and still others defer most of the decision making to elected or appointed officials.

At the state level, numerous departments may be involved. Their names may vary, and some states may subdivide duties in a way that does not exactly correlate to the typical state Department of Transportation (DOT) discussed here, which is responsible for developing and regulating transportation networks in the states, including roads, mass transit, public transportation, and pedestrian and bicycle travel.

Ideally, the department has an overall strategic plan for the role it plays in the growth and development of the state's communities, and for the state to encourage a balanced transportation system that meets local needs while being affordable. Federal law requires state departments of transportation to develop long-range plans but leaves their specific content to the states themselves.

Transit-Oriented Development

Because states' needs vary so much, so do the activities of transportation departments. New Jersey's overall plan is largely centered on transit, and it is the most prominent state to adopt an approach to transit planning called transit-oriented development. Transit-oriented development, which is also the policy model of the San Francisco and Salt

Lake City, Utah, metropolitan areas, is a model of development that focuses on increasing access to public transportation and increasing transit ridership—a particularly appealing approach in densely populated areas where traffic congestion has both social and economic consequences, even apart from environmental concerns.

The New Jersey transportation department distributes a handbook on transit-friendly land use policies to local New Jersey governments, in addition to operating a transit villages program, a public-private transit development program, and a program helping home buyers qualify for their mortgage by reducing their transportation expenses.

Transit villages are residential developments surrounding a transportation hub, with a small retail business component to help serve the shopping needs of the community. Transit villages are essentially residential developments optimized for public transportation users, in much the same way the suburbs that spread in the 1960s and 1970s were residential developments designed for frequent drivers (and in most cases, families with a minimum of two cars).

New Jersey has developed transit villages in Mercer County, Somerville, Hamilton Township, and along New Jersey Transit's Northeast Corridor, all under the name of the Transit Village Initiative. The Transit Village Initiative was founded in 1999 to offer an annual \$1 million grant to a municipality ready to begin a transit village project. Twenty-four different transit villages have been funded since then. Transit villages have also been developed in Miami, Florida, which has developed housing complexes around Metrorail stations, and Portland, Oregon, as part of that city's overall more sustainable and transit-friendly transportation plan. For further details see the entry on Transit-Oriented Development.

Transportation departments also typically oversee and coordinate the repair and maintenance of existing infrastructure, which throughout the country is badly in need of fixing. Despite the fact that half of the country's roads and bridges are poorly maintained, two-thirds of transportation funds in the country are used to build new roads instead. As mentioned above, Vermont is one state that has adopted a "fix-it first" approach to its transportation policy, assigning the highest budget priority to the repair of existing roads and to preventive maintenance.

Complete Streets

Transportation departments may also elect to adopt a “Complete Streets” policy, which was adopted as a federal policy goal in 2000. Complete Streets are streets that are equally accessible to residents with varying modes of transportation and level of ability, including motorists and transit riders, pedestrians, and bicyclists, taking into account the needs of the elderly, the disabled, and children. This means ensuring safety, paving shoulders or adding bike lanes, adding adequate and frequent crosswalks, and ensuring frequent-enough snow plowing and shoveling, as well as adequate drainage for rainwater.

Further, streets need to properly connect for multiple modes of transportation—sidewalks should not dead-end at the edge of a neighborhood, and bike coverage needs to be sufficient to allow bicyclists access to most of the city.

California and Illinois have passed laws requiring Complete Streets policies in transportation planning, while states like Colorado and Washington have worked to come closer to the Complete Streets goal. While Complete Streets plans can be adopted on the local level, street connectedness, bicyclability of neighborhoods that straddle town lines, and proper interlinkage of municipal transit systems can be difficult to ensure without state oversight. Typically, technical assistance programs and funding assistance are made available to local governments in order to help them do their part to meet statewide policy goals. For further details see the entry on Complete Streets.

Other Planning Departments

Transportation departments are not the only departments involved in state transportation planning, of course. Agricultural departments can set policies that guide the balance between preserving agricultural land so that citizens can obtain some of their food locally, and making land available for development. The Agricultural Security Area Program established in Pennsylvania in 1981, for instance, allows towns and cities to designate agricultural security areas where farms are given special privileges from government policies, encouraging their long-term planning.

Economic development departments can guide economic development by restoring Main Streets and downtowns, organizing brownfield cleanups,

and encouraging public transit, and can set policies to encourage commercial developers to make their neighborhoods pedestrian and bicycle friendly. Energy departments can support walking and bicycling by expanding commuter tax credit programs to include energy-saving commutes. Housing departments can provide incentives or tax credits to people who live near work or public transportation stops and are thus less likely to drive. Illinois reverses this, giving tax credits to businesses that are located near public transit and residential neighborhoods.

Education departments have a land use component to their planning activities, and many states assign, for instance, acreage minimums to schools, or other zoning requirements. Education departments can assist with planning where to locate or relocate schools in ways that serve the state’s transportation goals, while also coordinating school transportation policies, encouraging walking or bicycling to school, and establishing Safe Routes to School programs.

Colorado, for example, receives federal funding for a Safe Routes program that is distributed to support programs to relieve traffic congestion and high-speed zones in the vicinity of schools in order to create more routes by which children can walk to school.

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See Also: Complete Streets; Metropolitan Planning Organizations; Regional Transportation Planning; State Transportation Planning; Transit-Oriented Development; Transportation Impacts on Land Use; Transportation Policies, North American.

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Transportation Research Board

The Transportation Research Board (TRB) operates as one of the divisions of the National Research Council, which is a part of the National Academies, a private nonprofit organization, which includes the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The National Research Council provides independent expert advice and research services to the U.S. government, the scientific and engineering communities, and the general public. The work of the Transportation Research Board is carried out by 7,000 experts in the field of transportation. TBR's work is funded by the U.S. Department of Transportation, state departments of transportation, federal agencies, and various organizations and individuals.

History

In 1920, the National Board on Highway Research was created to serve as a clearinghouse for research on all aspects of highway technology. Five years later, the name of the board was changed to the Highway Research Board (HRB), which continued to coordinate research on highways. Daily activities were carried out by standing committees, and the group issued regular publications and held an annual convention.

In the 1950s, for the first time, the Highway Research Board began engaging in its own research projects, responding to research needs as they arose. In 1962, the HRB initiated the National Cooperative Highway Research Program (NCHRP) and extended the scope of the HRB's activities. In 1974, the name of the board was again changed, and the HRB became the TRB. In the 1980s, the TRB became involved in conducting research on national transportation policy for the first time. In the 1990s, the TRB's scope was further extended when the board was given responsibility for overseeing the Transit Cooperative Research Program and Long-Term Pavement Performance studies.

In the 2000s, the TRB manages Innovations Deserving Exploratory Analysis (IDEA) programs and continues to engage in cooperative projects that go beyond the scope of highway research, dealing with research issues such as airports and transportation of freight and hazardous materials. A major

focus of the TRB's current work is implementing the second Strategic Highway Research Program.

Committees and Task Forces

In January of each year, the TRB holds an annual meeting in Washington, D.C., that attracts 10,000 transportation experts from around the world. Approximately 3,000 presentations and 1,500 peer-reviewed papers provide insight into current research in all modes of transportation. The annual conference also provides an opportunity for committees and task forces to conduct meetings. Throughout the year, the TRB conducts other conferences and hosts workshops on transportation issues.

When the National Board on Highway Research was established in 1920, there were only three standing committees charged with providing and disseminating research on American highways. By the 21st century, the number of standing committees and task forces had grown to 1,200. The work of these groups is carried out by more than 4,000 transportation experts. The committees and task forces are organized into 11 groups. Six of these groups focus on the functional aspects of transportation, particularly on highways. The remaining groups deal with public transportation, freight, rail, aviation, and marine research issues.

Organization

Leadership within the TRB is provided by the executive committee, which is made up of members appointed by the chair of the National Research Council (NRC). Committee members include experts from the top tiers of the transportation industry and governmental transportation agencies and academicians who specialize in transportation research. The executive office of the TRB is charged with overseeing all programs and activities, working with committees and panels, preparing reports and various publications, conducting outreach, serving as a resource center, and furnishing staff support to the executive committee and the subcommittee for NRC oversight.

The TRB is organized into five major divisions: Technical Activities, Studies and Special Programs, Cooperative Research Programs, Strategic Highway Research Program 2, and Administration and Finance. The Technical Activities division is responsible for supporting standing committees and task forces; conducting field visits to transportation

agencies and academic institutions; and planning various meetings, conferences, and workshops. The TRB inherited the Marine Board in 1999 from another NRC unit and assigned it to the Technical Activities Division. The function of the Marine Board, which was created in 1965, is to coordinate research on all elements of maritime transportation with that of other disciplines.

The Studies and Special Programs division is responsible for convening special committees involved in policy studies, and reviews and prepares synthesis reports that come under the province of Cooperative Research Programs. The Studies and Special Programs division also maintains the Transportation Research Information Service (TRIS) database and provides library services.

The Cooperative Research Programs division is charged with overseeing the National Cooperative Highway Research Program, the Transit Cooperative Research Program, the Airport Cooperative Research Program, the National Cooperative Freight Research Program, and the Hazardous Materials Cooperative Research Program. The responsibility of the Strategic Research Program 2 division is managing a goal-oriented, short-term program that was created to gather research on advancing highway performance and safety. Financial and administrative support for the TRB is provided by the Administration and Finance division.

Cooperative Projects

Some of the most important work carried out by the Transportation Research Board involves research conducted in conjunction with other agencies and groups. As part of the first Strategic Highway Research Program (1987–93), the Innovations Deserving Exploratory Analysis (IDEA) Program was established to recognize innovative research in transportation. Subsequently, three separate IDEA programs were created. The National Cooperative Highway Research Program of the IDEA is supported by the Federal Highway Administration (FHWA) and operates in conjunction with the American Association of State Highway and Transportation Officials (AASHTO) to focus on innovative and nontraditional research in the areas of highways and intermodal surface transportation.

The IDEA Transit Program is supported by the Federal Transit Administration and the Transit Development Corporation. The focus of the IDEA

Transit Program is on technologies, methods, management processes, materials, and systems in the transit sector. The IDEA Intelligent Vehicle/Highway Systems (IVHS) Program is supported by the Federal Highway Administration and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA). Its focus is on innovative research in IVHS technologies in reference to highways, vehicles, intermodal surface transportation, and transit systems.

In 1997, the TRB's Cooperative Research Program and the Committee on Transportation Safety Management began working with AASHTO's Standing Committee on Highway Traffic Safety, the FHWA, and the NHTSA to identify 22 focus areas essential to improving safety on U.S. highways. A pool fund was established to implement the recommendations that addressed such subjects as roadway and infrastructure needs, drivers, vehicles, emergency medical services, and the traffic safety management process. The comprehensive plan produced by this cooperative effort came to be known as the AASHTO Strategic Highway Safety Plan. The Transportation Research Board subsequently published the *NCHRP Report 500: Guidance for the Implementation of the AASHTO Strategic Highway Plan*.

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See Also: American Association of State Highway and Transportation Officials; Federal Highway Administration; U.S. Department of Transportation.

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Transportation Statistics and Databases

Transportation statistics and databases offer a mixed blessing to practitioners in the field. By considering system requirements, components, and performance through statistical analysis, transportation managers and policy makers can make better-informed decisions.

On the other hand, to avoid becoming swamped by the rising tide of incoming data, these same professionals are compelled to learn new ways to handle the databases generated by their transportation domains. The information can help experienced managers balance operational data against strategic policy goals—but only if their mastery of the data exceeds or keeps pace with the sheer volume of data and allows them to separate signal from noise.

Complex Settings and Uses

Understanding transportation systems in their diverse modes, settings, and purposes is a complex task. Many data sets and statistical bodies are linked to a large number of different markets, demographic groups, and geographically distributed activities. Some of the transportation modes are operated in extremely competitive markets, while others are over-consolidated or monopolistic; some are highly regulated, others less so. Some are dominated by private operators, some by public, still others by hybrid forms of ownership and operation. Each of these scenarios and contexts tends to create statistical data of varying degrees of accuracy and accessibility.

Some transportation systems require great fixed capital assets and infrastructure. Others represent emergent modes or intermodal forms that will be altered in their effect and scope by virtue of their increasing connection to the existing networks



The Moving Ahead for Progress in the 21st Century Act (MAP-21) is a bill to govern U.S. federal transportation spending. It was passed by Congress and then signed by President Barack Obama on July 6, 2012. Accurate statistics play a paramount role in the success of such bills and in achieving goals such as alleviating traffic congestion and reducing the federal budget deficit.

of separate technologies and their intelligent and opportunistic use of available data.

Among the kinds of data that provide inputs, or raw statistics, for database management systems to compile and sort are supply and demand, current and future needs, local and regional economic and demographic trends, monopolistic structures and competitive forces, fixed costs and variable prices. To make sense and practical use of this wealth of often counterweighted data, information management systems must not only take it in and sort it, but the type and scope of outputs also must be considered in terms of form, size, flexibility, searchability, and appropriateness to the policies in place and the tasks that need to be completed.

Another type of metric is also involved: the human factor. For utility in this area, a database must help its users grasp and interpret such “fuzzy” data as transportation customers’ willingness to pay, their perceived value of service, and their perceived value of alternate or comparison services. Ideally, a database can handle humanistic input variables—such as lower travel cost or the seasonal desirability of particular destinations—in such a way as to generate output that can help transportation administrators and managers predict shifts in demand over the near and long term and plan accordingly.

Available Resources

There are several categories of statistical and database resources that apply to nearly all transportation planning needs and operational applications. These in general comprise (1) university and college departments; (2) federal, regional, state, and municipal transportation and public policy agencies; (3) professional and trade group best-practices boards; (4) social science and public advocacy institutions; and (5) private enterprise technical departments. An example of each includes:

1. Inter-University Consortium for Political and Social Research, which has published and archived such works as the Metropolitan Travel Behavior Survey Series, originally conducted by the University of Minnesota using federal funding. The series includes individual and mass transit data collected in 22 metropolitan markets across the United States, ranging from the Baltimore Travel Survey of 1977 to the Midlands Tomorrow Household Travel Survey of 2006–2007, covering the Columbia, South Carolina, metro area.
2. National Transit Database (NTD) of the Federal Transit Administration, established by Congress as the chief repository for transit system data, statistics, surveys, and reports. The NTD imposes uniform reporting standards across its data sources and their outputs, and takes in comprehensive reports from nearly 700 urban transit system operators across the country, as well as a number of rural system operators. The NTD comprises data mainly from rail and bus systems.
3. Institute of Transportation Engineers, which makes available information on operational standards, technical specifications, and related data as it applies to the design, engineering, upgrading, and troubleshooting of transportation infrastructure signaling, monitoring, and management technology. Datasets are developed and provided on topics as technically driven as “Object Definitions for Dynamic Message Signs” and those as broadly sourced as “User Comment Disposition Summary for NTCIP 1203 v02,” which indexes field data and troubleshooting results on a variety of technology installations.
4. American Public Transportation Association, an advocacy group that underscores the benefits of public transportation policy advances through its print and online publication of data such as its quarterly “Ridership Report” on public transit usage; its Public Transportation Investment Background Data series, covering the financial statistics on transit funding sources and the outcomes projected from scaled levels of investment; and such data-rich reports as its “Trends in Public Transportation Vehicle Fleets” report.
5. Bombardier Insight, a division of the corporate communications unit of this transportation manufacturer, which through its Expert Library project provides widely sourced statistics on a range of topics

under the headings of mobility, urban congestion, economy, society, and productivity. The online-based Expert Library comprises internal data sets and graphics; survey statistics and analysis linked to news-gathering companies based in Asia, Europe, Africa, and elsewhere; academic reports; and data from such diverse bodies as the Railway Association of Canada, the United Nations Development Program, the British Council, and ClimateProgress.

Performance Management

Statistics and database management underlie the ability of transportation authorities to provide such information-intensive functions as active traffic management and dynamic pricing of tolls. They are also key to selecting, applying, and controlling the growing array of techniques applicable to multimodal and demand management, including smart growth planning, flexible dispatch systems, automated rolling stock direction, options for telecommuting, and on-demand car and ride sharing.

Areas that require continuing information appraisal and statistical report review include the decision-making process for providing the necessary levels of operating support functions, as well as the decision-support methods that provide intelligent means to implement and use performance measures and to continually refine management processes.

A great deal of this type of support can be considered under the rubric of performance management. For instance, the Federal Highway Administration (FHWA) Office of Operations has identified the principles and tools of performance management as essential to improving transportation mobility and efficiency in the United States—among the leading policy mandates of every transportation agency, whether operating at the federal, state, regional, or local level.

Reducing congestion, a fundamental metric of improving system reliability in any transportation mode, can tap a particular aspect of performance management often called mobility monitoring. This refers to identifying mobility-based system performance metrics, interpreting the trends that emerge from the data, and generating reports to inform

both policy makers and operational decision makers. In the process, FHWA stipulates, “Mobility and reliability measures are identified that communicate well to both technical and nontechnical audiences.”

The agency suggests that performance management mobility monitoring be tuned to measure and review the data that will be needed to answer certain questions as operations and operational conditions are modified over time. These questions ideally include the following:

- Where and when is the transportation system congested and/or unreliable?
- What operational improvements are working and where?
- What transportation improvements are needed and where?

As an example of the sensitivity to unique factors that must be accounted for in the data accumulation and evaluation for research of a given mode of transportation, the FHWA posits the example of a contrast in modes. In its consideration of the function of fully access-controlled highways (such as the interstate highway system), the FHWA notes that the essential goals of the system include mobility and speed-of-person and speed-of-freight movement.

This is in contrast to urban thoroughfares that must support a number of countervailing goals that are distributed across a number of quite diverse users, such as bicyclists, pedestrians, private automobile drivers, and mass transit users. Therefore, the creation and application of appropriate performance management statistical metrics must be structurally and contextually different for each of these modes.

Performance management systems are being developed for, and will continue to be refined to maximize the use of, the ongoing expansion of wireless sources that can provide real-time data from a plethora of originating points and in a broad range of statistical categories. Radio frequency identification (RFID) systems, smart card readers, mobile devices, and increasingly data-connected vehicles hold much potential to supply decision-making and performance-monitoring systems; yet they also hold the risk of overwhelming such systems, or disproportionately emphasizing information that is less than vital.

Nevertheless, performance data is likely to eventually become widely available for all modes, all links and intermodal stations, and most geographic locations. The FHWA plans to help manage the convergence of collection of data that, in addition to average speeds and travel times, would feature the more qualitatively tuned results such as day-to-day trip reliability, trip origin and destination, and traveler satisfaction. These metrics will obviously call for more sophisticated processing tools, including various amounts of artificial intelligence handling.

Toward this policy goal, the United States Moving Ahead for Progress in the 21st Century Act (MAP-21), enacted in 2012, enumerated performance management as a core element to make various individual and combined transportation modes in the United States more efficient, effective, and predictable. MAP-21 provided more than \$105 billion to fiscal year 2013 and 2014 budgets for surface transportation. Within these budgets, MAP-21 stipulated performance goal metrics on a national basis for the following:

- Safety
- Infrastructure condition
- Congestion reduction
- System reliability
- Freight movement and economic vitality
- Environmental sustainability
- Reduced project delivery delays

Governmental authorities active in each of these policy areas have been charged with devising ways to “do more with less.” This is a core tenet of MAP-21; the flip side of this policy priority is to apply advanced technology, smart systems, real-time feeds, statistical tools, and database analysis to provide the means to do so. As such tools themselves are currently in widely different degrees of development, and as they are constantly being reviewed and refined, this means the hunt for innovation will rely as much on judgment as on raw information.

Well-organized, searchable, and fully accessible data on system performance is key, but is in some ways only a beginning. Practitioners of transportation innovation must tap their data sources not only as a means of answering questions but as a way to gain insight into what the next questions will be.

Weighing Costs and Benefits

Among the more valuable findings possible from many transportation database instruments now applied across various transit modes are insights into which constituents win and which lose. Perhaps put less crudely, this question can be expanded to query who and what are the individuals, groups, metropolitan and rural jurisdictions, environmental ecosystems, economic sectors, and transportation programs and policies that stand to benefit from the implementation of a particular decision—and which among those parties stands to pay some type of cost.

Decision-making output derived from this set of questions generally has important influence on the reality and perception of changes to a transportation system as the ramifications of those changes are experienced by (1) individuals, (2) government bodies, (3) private operators, and (4) ancillary agents such as insurance providers.

Therefore, the diversity of database statistical modeling systems and their output are of concern, especially when seeking to contrast and compare decisions made across many different scenarios and when seeking some degree of uniform reliability about how various parties will be affected by transportation decisions.

A range of metropolitan planning organizations (MPOs) were surveyed by the Transportation Research Board (TRB) on the subject of what types of data modeling they employed in their travel-demand-forecasting role, and the TRB found “that there are considerable variations in the completeness and complexity of the models and data employed,” further noting that “MPOs vary significantly in the number of staff devoted to travel forecasting.”

In this study, the TRB reported that a large majority of the MPOs said that they utilize a four-step research model. This approach uses survey and other data to estimate future trips; it also statistically assigns those future trips to various travel modes. Seven of the responding MPOs surveyed indicated that they employ activity-based models.

This type of statistical modeling tends to be tied more closely to sociological elements, such as household makeup and traveler characteristics and behavior, and therefore activity-based models should in concept permit the MPOs to address policy questions that conventional four-step models

are especially ill suited to handle. For example, four-step models are not readily employed to handle the task of estimating the emissions effects of small transportation projects; they also would not be facile at linking data on these effects to air quality over all in a given statistical area. The more advanced, or subtle, database modeling techniques, of which activity-based models are one type, are needed to reliably estimate such outcomes.

System Effectiveness

One measure of the effectiveness of a database modeling tool is how much it helps operational managers and staff speed up good decision making by virtue of being presented with simpler choices. This is apparent in such systems as train rescheduling, where deviations from scheduled operations have immediate rippling effects that need swift detection, reaction, and resolution. Train dispatchers, through experience as well as trial and error, have built up a sound knowledge base that permits them to employ logical simplifying rules in order to judge deviations with a high degree of reliability and then to quickly make and implement decisions that resolve the conflicts stemming from those deviations.

Statistics-based decision support tools can help dispatchers in this process—but only if they can accurately and rapidly predict any cascading implications of the various solutions employed to resolve deviations. Software developers have worked on upgrading such tools by working with train scheduling personnel. Experienced dispatchers have been able to test these tools by filling in any blind spots the researchers might have had.

In just such a developmental experiment with Turkish State Railways, the dispatchers and software developers were successful in using genetic algorithms to supply conflict resolution solutions. In order to faithfully mimic the decision behavior of dispatchers within the automated operation of the software, the experimenters crafted artificial neural networks. Results were promising and lend insight to the expanding role that advanced statistical and database technology and techniques may hold in improving transportation problem-solving and decision-making challenges.

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See Also: Highways, Social and Economic Impacts of; Intelligent Transportation Systems; Transportation Cooperative Research Program; Transportation Research Board.

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Transportation Studies

This field studies the movement of people and goods via alternate modes of transport, such as road, rail, water, and airways. It analyzes the transport system that facilitates the movement of commodities and its relationship with various dimensions of economic development such as economic growth, industry location, land use, sprawl, energy, pollution, and climate change. It is like any other factor of production and, hence, there is demand and supply of transport.

The means of transport provides a vital link among production centers, suppliers, and market areas. Transport is a derived demand and improvements in it are expected to be followed by economic development. It plays an important role in economic development by providing a unifying and integrating influence upon the economy.

This field is interdisciplinary, and has had a long-term symbiotic relationship with the disciplines of civil engineering and economics, thereby embracing the quantitative approach to build mathematical transport models. Further, it has been influenced by other cognate disciplines such as transport logistics, planning, geography, and geographical information systems (GIS).

Transport geographers study the spatial patterns of transport networks and nodes and how this eases the friction of distance, thereby shaping land use and settlement systems. During the 1950s, the advent of the interstate highway system in the United States connected cities and towns, made some places more accessible, and led to the demise of other locations.

North American geographers during the 1960s heralded the building of highways with quantitative modeling and applications to understand the spatial aspects of transport. The field received considerable impetus from the federal government in the 1970s because of its interest in regional transport policy issues such as railroad reorganization and abandonment, intercity bus deregulation, airline passenger transport deregulation, motor carrier deregulation, and energy and environmental problems related to transportation.

Study Areas for Transport Geographers

Transport geographers since then have worked in four major areas, focusing upon structure, growth,

and development of transport networks; spatial interaction; travel patterns; and GIS.

The network analysis research tradition took off in 1970 with the publication of R. J. Chorley and P. Haggett's *Network Analysis in Geography*. Transport analysts study nodes, links, networks, and systems. Links between nodes either by a single mode or several modes lead to the emergence of important nodes. Further, a pattern of links produces a network and the provision of a physical arrangement of transport infrastructure generates a transport system.

The relationship between transport network and development was examined for Ghana and Nigeria in the early 1960s. The conceptual model proposed the development of a series of coastal ports, followed by the development of a series of feeder lines, leading to extensive interconnection and the development of routes of dominance.

This model has been criticized for its oversimplification and several questions have been raised: How do developing countries make a transition from one stage to another in the development process? How far does the model represent the development needs of the host country rather than the aspirations of the colonial power? Are there overlaps with the models of transport development in developed countries?

The Airline Deregulation Act of 1978 in the United States put an end to the oversight by government of fares, routes, and market entry of private airlines. This policy change led to the development of the current hub-spoke network structure of air travel in the United States. Such a network configuration brings economic advantage to certain nodes (that is, the hubs), which become centers of commercial success while airports located at the extremities of a spoke face economic decline.

One author examined the changes in the centrality of hubs resulting from global airline industry deregulation. The analysis indicated that the hubs in the poorest developing countries, such as those in sub-Saharan Africa, became relatively inaccessible and isolated, while the emerging economies in the western Pacific Rim of Asia gained markedly in their accessibility.

There has also been interest in understanding the hub-spoke network as an outcome of a network design problem. Studies on network design have found theoretical reasons for the rise of hub-spoke

networks, the location of hubs, and their evolutionary trajectory. Clearly, the hub-and-spoke network has emerged as a distinct area of research in transportation studies in conjunction with location analysis and network design.

In transport geography, much of the research has examined spatial interaction ideas, such as complementarity, transferability, and intervening opportunity. Complementarity implies there is demand for a good or service in one region and an other region supplies it. Transferability implies the product needs to be shipped at an acceptable exchange rate or cost of transport. Intervening opportunity implies there should be a lack of an alternate source of supply or excess supply in relation to demand.

Several quantitative methods have been utilized to study transportation problems, such as the gravity model, entropy-maximization model, logit-choice models, and trip-chaining models. A family of spatial interaction models has been developed to construct predictive estimates of volume of flows between locations.

The flows in these models are a function of the distance between nodes, demand for goods and services among cities, and the ease of movement among various modes by alternate modes of travel. There have also been calls for an increasing role for modeling in the areas of land use, investment, pricing, and regulatory policies in response to increased traffic congestion in metropolitan areas. In transportation geography, this relationship among modeling, prediction, and planning has been exceedingly important.

Travel patterns and variations in them have interested transport geographers. Analysts have observed that travel patterns peak at morning and evening hours of the day. The movement patterns in rural areas reveal seasonal and weekly peaks. But the question that needs to be asked is, what factors explain the observed variations in urban and rural areas? And, are there differences in the movement patterns among male and female travelers in rural and urban areas?

The notion of job and housing balance became important as a strategy to address the suburban traffic congestion problem resulting from increased commuting between work centers in the central business district and the suburban fringe where people resided. Analysts have noted that if adjacent localities near employment centers had developed

affordable housing, less traffic would have been generated on highways.

In transportation planning, GIS is an information system specializing in the recording of digital information and managing and processing information that is spatially referenced. A branch of GIS applications specific to transportation is called geographical information systems for transportation (GIS-T).

The Bureau of Transportation Statistics (BTS) in the United States collates several databases related to transportation including network databases, surveys of human travel behavior, and studies of commodities flows. There are three ways to approach GIS-T and they are data representation, analysis and modeling, and applications.

First, data representation is the core of GIS-T research because data has to be represented in a way that can be readable in a GIS environment. A very important strength of GIS-T is that it can integrate both spatial and nonspatial data for purposes of display and manipulation. There are two basic data models of representation: object-based data model and field-based data model. The former model is suitable for features that are discrete and identifiable such as points, lines, and polygons. The latter model is suitable for features in geographical space that are continuous.

Within GIS-T, for instance, network analysis is represented by a set of nodes, interconnected by links. The object-oriented data model is suitable for transport applications. GIS-T also has developed several unique applications, such as shortest path and routing algorithm, spatial interaction models, network flow problems, facility location problems, travel demand models, and land use transportation interaction models. GIS-T has a wide variety of applications, including transport and logistics, transport safety analysis, transit planning operations and control, routing, and scheduling.

Logistics and Supply-Chain Study

Business logistics as a field of inquiry was born in the 1960s. It studies the movement of goods, products, and services from the production to the consumption and waste disposal stages in both forward and backward directions in order to maximize value addition and customer satisfaction.

Transport is an important component of the set of physical activities in the production process and includes such activities as supplying inputs to

manufacturing plants, warehousing services, and merchandising establishments. An efficient transport system is a precondition for business logistics because it improves overall efficiency, reduces operating costs, and promotes service quality.

An efficient transport system makes the product movable, improves regional efficacy, and enhances the competitiveness of production and sale of goods. The business literature on logistics and transportation has embraced the rise of just-in-time delivery, express logistics carriers, and the move to supply chain optimization, which reflects the importance of information on logistics.

Supply-chain optimization is a set of mathematical techniques applied to ensure the optimal operation of a manufacturing and distribution supply chain. This process entails placing inventory within a supply chain and the minimization of transport costs. This procedure entails the application of computer software and mathematical programming.

A supply chain can be represented in terms of network models where the supplier may own factories that manufacture component parts and ship them to customers, who are the assembly plants, located elsewhere for building and testing products.

Subsequent to the seminal publication of the 1959 book titled *Economics of Competition in the Transportation Industries*, the subfield of transport economics took off. This treatise by J. Meyer et al. addressed a comprehensive analysis of transportation resource allocation problems utilizing statistical techniques for empirical analysis.

Economics of transportation has broadly addressed themes such as demand, supply, investment, regulation, and the environment. Demand for transport has been studied mainly for estimating key parameters of the users of various transportation modes with respect to modal attributes such as price, quality of service, and speed.

Supply of transport has been concerned with the estimation of a firm's cost function (for example, the existence of scale economies in various transport industries). Such an analysis is useful in evaluating whether freight and passenger transportation services are provided at the lowest cost to society; further, it helps in identifying if one mode of transport has an advantage relative to another mode. Subsequently, cost function estimates provide insights to productivity growth in different transport industries.

Investment analysis is concerned with determining the net present value (NPV) of future streams of revenue and costs by discounting with a rate of return that calculates the marginal productivity of capital in alternative uses. Transport analysts were interested in controlling natural monopolies to ensure that passengers and freight would not be charged tariffs and fares priced higher than they could bear. Railways, for example, were known to discriminate against modes of transport serving the individual passenger and therefore needed to be regulated.

Finally, transport is a major consumer of energy and a source of pollution. The emission of hydrocarbons and the production and consumption of fossil-based fuels raises the question of long-term sustainability of current transport systems.

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See Also: Airport Hubs; Geographic Information Systems in Transportation; Just-In-Time Systems; Network Modeling; Supply-Chain Management; Transportation Statistics and Databases.

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Transportation Surveys

A transportation survey is a data collection tool used to gather transportation-related information about individuals or groups. Transportation policy makers at all levels need sound data to make decisions about program design, policy choices, and accurate forecasting, as well as for effective monitoring and evaluation. Smart decisions for planning and implementing decisions about transportation require comprehensive, precise, and up-to-date data about travel demand, infrastructure condition, travel time reliability, the equity of access, and environmental impacts.

Transportation surveys of various types allow researchers to collect large amounts of information in a relatively short amount of time and to do so at a lower cost than other data collection strategies. Traditional survey methods have included paper-and-pencil questionnaires and interviews conducted in person, via mail, or by telephone, but advances in technology in recent years have changed the ways in which transportation data is collected and analyzed.

Types

Transportation data are related both to the spatial elements of a particular area and to the transportation network (roads and public transit). Land use surveys, those that study and record the ways

land is being used in a particular area, are an integral component of transport planning information requirements. Because travel is a "derived demand," meaning that it has no inherent value but only worth that rests in its facilitation of other activities, transportation researchers need information about the location and intensity of land use activities.

The transport system inventory survey also provides transportation researchers with vital information. The transport system connects land uses, and the volume and frequency of travel that occurs between land uses depends upon the quality and quantity of the transport system inventory. Thus, surveys of the transport system inventory, including both public and private modes of transport, are necessary.

Such a survey will yield information on the right-of-way (the length, direction of movement, capacity, and design standards of roads and tracks), terminals (the location, throughput capacity, and holding capacity of public transport stations, modal interchanges, and parking stations), and vehicles (the number, passenger or goods capacity, comfort level, and various operating characteristics of both public and private vehicles).

Travel pattern surveys also provide needed information on land use activity and a transport system. They reveal the travelers, their destination, and the time, mode, route, and purpose of the trip. Transport system performance surveys measure performance characteristics, such as travel times, travel time variability, passenger waiting times, vehicle occupancies, and system safety. They disclose whether the transport system is handling efficiently the demands being placed on it.

All of these surveys are concerned with collecting data about the transportation system as it exists, but transportation planners are often also required to offer credible predictions about future demands on a transport system as a result of changes in the system or its operating characteristics. Such predictions utilize demographic and socioeconomic surveys within the overall transport survey framework. Personal and attitude surveys can provide useful information concerning how individuals react to actual or perceived changes in the system.

Transportation surveys provide transportation planners with data that include passenger and freight information on volume, origin, and destination flows; costs of travel; impacts of travel influences

on demand; and substitutes for travel. Sound data enable transportation planners not only to plan for the future effectively but also to solve problems and sound warnings. Good data from surveys can show how best to relieve congestion, improve supply-chain connectivity to make freight transportation more competitive, and help consumers and providers to use the transportation system more efficiently. Freight transportation volumes can indicate changes in the economy at an early stage.

National Household Travel Survey

Among the best known travel surveys is the National Household Travel Survey (NHTS), a survey conducted approximately every five to seven years under the auspices of the U.S. Department of Transportation and funded through the Bureau of Transportation Statistics and the Federal Highway Administration. Its purpose is to gather information on both long-distance and local travel by the American public. Department of Transportation officials use the data to evaluate and review current programs and policies, study mobility issues, and plan for the future. States and metropolitan planning organizations find the data helpful for similar purposes.

Others who find the data useful include academics, consultants, and government officials outside the Department of Transportation who are interested in such information as travel behavior at the individual and household level, the relationship between demographics and travel, and the public's perceptions of the transportation system.

Some of those who use the data are less directly related to transportation. Medical researchers base determinations of the crash exposure rates of drivers and passengers on NHTS data. Safety specialists use the data to study the accident risk of school-age children, particularly when they are traveling on their own by walking or biking. Social service agencies are interested in how low-income households currently meet their travel needs.

Technology and Changes

Transportation surveys evolve with changes in the greater culture. In the 1970s, face-to-face interviews of randomly selected households and mail surveys yielded to random digit dial phone surveys. Two decades later, computers were used for electronic data collection through computer-assisted telephone

interviews, personal interviews, and self-interviews. In the 21st century, the Global Positioning System (GPS) is common in automobiles, cell phones have largely replaced landlines, market research regularly mines the Internet, and a variety of social media have transformed communication. Each of these technological advances has affected transportation surveys.

Transportation researchers, who suspected travel diarists often underreported their travel, have wished for a reliable means of quantifying data collected in this manner. Passive location data collection technologies, particularly GPS, can collect precise data on location, position, and speed. GPS-collected data first formed part of a major household travel survey in Austin, Texas, in 1997. Similar surveys have since been conducted numerous times, and transportation researchers believe GPS-only household travel surveys are a likely direction for future household travel surveys such as the national survey.

With costs of transportation surveys rising and funding shrinking, social media offer an appealing new means of conducting surveys. The top social media sites offer a broad sample of respondents; 56 percent of Americans have a social networking profile. Facebook, still the largest of an ever-growing number of social media sites, boasted 1.15 billion active users as of September 2013, and Facebook profiles typically include general demographic, educational, and geographic information, all of which can be useful in transportation surveys.

Internet-based surveys also offer the possibility of enhancement with images and audio, and the response rate for Internet-based surveys has been shown to be more than 10 percent higher than that of telephone surveys. These attractions are offset by the fact that social media users do not reflect the demographics of the United States. More users are female and urban, and young adults ages 18 to 29 are disproportionately represented.

Although 2013 statistics suggest greater ethnic, racial, and economic diversity among social media users, Internet access from home is still heavily skewed, with 76.2 percent of non-Hispanic whites and 82 percent Asians having access, compared to 58.3 percent Hispanics and 56.9 percent African Americans. The poor and the elderly are also less likely to have Internet access. Nevertheless, Web transportation surveys will likely be used with increasing frequency in the future, perhaps in conjunction with e-mail or traditional telephone-based

interviews, to add to information data collected from travelers.

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See Also: Federal Highway Administration; National Household Travel Survey; Origin–Destination Models; Traffic Studies and Surveys; Transportation Impacts on Land Use; Transportation Studies; Travel Surveys.

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Travel by Households

One of the prime motivations transportation professionals have for moving away from a traditional four-step travel demand model toward more advanced models has been to capture the interrelationships in travel among family and/or household members. The travel behavior of one household member can influence the travel behavior of other members in a variety of ways: trip generation may be impacted either positively or negatively, joint travel may be scheduled (and this desire to travel together may impact trip scheduling), and mode choice may be impacted in several directions.

While tour-based models do assert consistency in mode choice between half-tours (a significant improvement over trip-based models), they are not able to link travel behavior across individuals, which has led academic researchers and, increasingly, planners at planning agencies in larger metropolitan

areas, particularly in the United States, to research and implement activity-based models.

Household Impacts on Trip Generation

Household members can influence each other's travel behavior for mandatory travel, such as work or school tours, as well as non-mandatory tours. One common pattern is that when a child, particularly a young child, is home all day (does not travel to school), then an adult generally forgoes all other work and nonwork travel for that day.

When a worker and a nonworking adult are in the same household and one must care for an at-home child, the nonworker is by far the more likely to provide care. It should not come as a surprise that gender plays a role here, with adult females more likely to take care of children, even in the case when both household heads are full-time workers. In nontraditional households where retired adults are living with working adults, the senior household members often will fill in for a worker if a child is sick.

Another important observation is that certain needs (that must be satisfied by travel) are generated at the household level, but can then be allocated to a specific household member. This is most commonly seen in the case of shopping for groceries. Once this need has been satisfied, the maintenance travel of the remaining household members decreases. Larger households generate more travel than smaller households, all else being equal, but they often make fewer maintenance tours (or maintenance stops) on a per-person basis, though this does not necessarily hold true for discretionary travel.

Indeed, once one household member makes a discretionary tour, such as a social/recreation tour or an eating-out tour in the evening (as opposed to an at-work lunch activity), this may increase the likelihood of other household members also participating in a discretionary tour, precisely because this activity is often a shared one (that is, it is a type of joint tour). Seniors are observed participating in household joint travel, but at a lower rate relative to working adults and children.

When university students are living at home, they typically have the least interrelated travel of any of the person types, infrequently participating in household joint travel. University students are also the least likely to stay home to care for a sick child in the household. At the same time, they tend



The questions studied in travel behavior are broad and are very much related to activities of the typical household. Households with children are more likely to have parents who drive their children to school or to a day care center. For working parents, children are often dropped on the way to work, but the return trip may be more of a challenge since school hours typically end several hours before working parents are available to pick them up.

to have the lowest claim on household vehicles, so their interaction with other household members and their travel arrangements is quite low.

Impacts on Joint Travel and Trip Scheduling

Household members can make a variety of types of joint travel arrangements: joint travel where the activity and tour characteristics of the entire tour are shared by two or more household members, or partially joint travel. Typical examples of this include tours where household members share the inbound or outbound half-tour, but then the other half-tour is made independently with a different mode and/or different time-of-day characteristics, or escorting behavior where only some of the household members participate in the main activity and the other member(s) are simply there to provide transportation.

Joint travel behavior is actually quite prevalent, but only for nonwork travel. It is comparatively rare for two household members to have identical work

tours, as opposed to a situation where members coordinate travel but with different destinations or one member drops another member at a rail station, for example.

Joint travel between household members is being introduced to activity-based models in a gradual fashion with the focus on fully joint tours for non-mandatory trips, particularly shopping and social/recreation trips. The most complex intra-household behaviors being modeled involve escorting school children to school, which may involve coordination of two (or more) mandatory tours, given that multiple children may be being escorted.

In North America, parents are increasingly driving children to school (or to day care services). If the parent is a nonworker, this is typically an escorting tour, where the primary purpose is to deliver the child (or children) to school. However, for working parents, the child is often dropped off on the way to work. This requires coordination on the outbound leg and more significant adjustment on the inbound

leg, as school days frequently end several hours before working parents are available for pickup.

Families with younger children may turn to day-care services to bridge this gap, though this does not eliminate the need for coordinating household travel patterns at some level, given the penalties incurred if children are picked up after the agreed time. Households have come up with a number of coping strategies, including having children return from school on their own, having children participate in after-school care or after-school activities, having one working adult choose part-time work over full-time work, or having a different household member (with staggered hours) pick up the children on the return leg.

In some cases, households even cope by coordinating between households through multi-household coordination or carpooling, though in some ways this multiplies the difficulties inherent in coordination. Just as in the case of staying home to care for a sick child, if there is any escorting of children to school, it typically falls to female adults to engage in this escorting, though there are certainly exceptions to this pattern.

Coordination between household members is particularly important if escorting children to school is an activity the household engages in, but it is just as important if other joint travel is to take place. In order to understand (and predict) this behavior, time scheduling models take on considerable importance, well beyond the time-of-day factoring found in more trip-based travel-demand models. Some researchers have investigated not only scheduling but rescheduling models in order to find out how household members are able to coordinate their activities in order to fulfill their desired joint travel.

Household Impacts on Mode Choice

Mode choice, while often viewed as an individual decision, is impacted in a number of ways by the other household members. In the first place, car ownership is heavily influenced by household size and composition. Larger households and particularly households with two or more children are more likely to possess one or more cars.

Workers in households and household auto ownership are strongly positively correlated. Car ownership in and of itself tends to increase the use of car modes, but there is an important

caveat, which is only gradually being introduced into activity-based models, and that is the matter of car allocation. If there are fewer cars than licensed drivers in the household, then a car may not be available to everyone who wishes to use it to complete a tour. At the same time, it is clear from observations that many households do work out car sharing arrangements and rearranging of schedules to allow for dropping off and picking up of children and adults who lack a car (or prefer not to drive for a variety of reasons).

The allocation of vehicles within the household is another area for further research. In certain households, there is clear competition over the vehicles between the working household head with the longest work commute and the household adult (working or not) with the most child escorting duties. At the same time, it should be emphasized that this is a relatively rare situation in North America, where most households (at least those not living in the urban core) possess sufficient vehicles to avoid significant conflict over vehicles. Nonetheless, when vehicle type, age, and fuel efficiency are considered, there may still be competition over which vehicle is being used for which travel purposes.

Without understanding (and accounting for) these household dynamics, it would be hard to explain (and model) why so many school trips, in North America at any rate, are made via a shared-drive mode. Explicit consideration of joint travel also gives a much better understanding of why fully joint travel behavior is so commonly made as a shared drive tour. Joint travel tours are commonly made by driving and to a lesser extent by walking, whereas joint travel made by transit is infrequent. Without considering and modeling these tours as joint tours, to say nothing of modeling tours rather than separate trips, the shared nature of travel by household members cannot be captured.

Understanding of Household Travel

At minimum, understanding what portion of travel is individual based and what is household based will give researchers and planners a fuller understanding of the trade-offs already made by travelers. This may lead to different policies, such as a greater focus on increasing intra-household joint travel rather than inter-household carpooling.

When models can reveal that certain seemingly independent auto trips may actually be partially

joint travel involving pickup and drop-off of other household members, it becomes more apparent that these drivers may be considerably harder to switch to other modes than conventional models would indicate, particularly four-step trip-based models that have no linkages across travel behavior throughout the day. The trade-off is that attempting to represent more fine-grained behavioral realism requires increased complexity in travel demand models.

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See Also: Activity-Based Models; Travel Demand; Travel Modeling; Travel Patterns of Women.

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Travel by Mode

The analysis of transport mode use is essential to understand and/or forecast travel behavior, and therefore to respond to planning needs. Given the strong economic, social, and environmental stakes related to transport mode use, especially car use, a considerable number of empirical or theoretical works can be found in the last decades.

Various transport mode segmentations are available that depend on several dimensions. Distance consideration impacts the transport mode choice; for example, air transport is not relevant for urban

areas, or the option of walking for longer distances, except as a feeder mode.

Distinction between motorized and nonmotorized modes is significant when environment concern is important. Public versus private mode is also generally taken into account. But, available transport modes evolve, with new modes (for example, rent services like self-service bicycle, car sharing, and motorbike taxis) that contribute to reducing the frontier between private and public use.

Finally, more concern is being given to intermodality (that is, combination of several transport modes within the same trip) and multimodality (that is, use of different transport modes for travel over the course of the day or the week). This article first presents car use and the need to reduce its usage and then focuses on the main determinants of transport mode use.

Can We Reduce Car Domination?

Throughout the 20th century, the car has expanded its share against all other modes in nearly all market segments in most Organisation for Economic Co-operation and Development (OECD) countries. In OECD countries, individuals without car access are a minority, although they represent an increasing concern because social inclusion and equity—which can be negatively impacted by limited mobility—are receiving more and more attention in transport planning.

However, car domination is not universally true. In sub-Saharan African cities, only a minority of citizens (the richest 10 percent) regularly use a car for their daily mobility. In some developing countries, various forms of formal and informal public transport or individual modes (for example, bicycles, motorized two-wheelers, or walking) still have higher modal share than private cars. Nevertheless, in countries with high economic growth such as China, similar trends in car use growth, as in OECD nations during the 20th century can be observed.

With varying degrees of intensity, all industrialized countries have put car use reduction on their political agenda. This evolution meets various objectives. First, environmental concerns (greenhouse gas emissions and other pollution) demand restraint of the most polluting modes, such as private car.

Traffic congestion also represents an important economic loss, and most experts agree that it can no longer be mitigated by infrastructure



In India, walking, pushing, or towing with or without the assistance of an animal is still an important mode of transportation in most urban areas. To further improve conditions for pedestrians, Mumbai has commenced the construction of more than 50 skywalks, as part of the Mumbai Skywalk project.

development. Equity and social inclusion require the development of alternatives for those who do not have access to car.

This has explained the development of public transport to some extent. Especially in European countries, development of public transport is favored not only for social equity but also for economic and environmental reasons.

More recently, nonmotorized transport modes have received more attention. Of course, they respond to environmental concerns and they also represent an economic solution both for individuals and for transport authorities. They also respond to the growing concern for transport solutions to health-related issues. Walking and cycling, used as a sole mode of transport on whole trips or to access public transport stations, are highly recommended as a way for city

dwellers to perform daily physical exercise in order to curb obesity and health problems.

All these developments in transport are increasingly interacting with built-environment concerns, which are receiving growing interest from researchers and practitioners. Car reduction targets are most commonly defined in urban planning, but success in meeting these requirements requires understanding the reasons for car use and the mechanisms that might result in switching to other transport modes.

Travel Mode Determinants

A considerable amount of work focuses on mode-choice understanding. Most determinants fall into four broad categories: The first, trip characteristics, includes purpose, origin-destination (OD), distance, and monetary cost, which impact mode use. In industrialized countries, modal share of walking is mainly restricted to trips of less than one mile. Cycling usage is strongly decreasing for distances of more than 3 miles, except in certain countries such as the Netherlands and Denmark. Monetary factors (gasoline, car parking, etc.) can strongly impact car use, especially in most central areas of European cities. The cost of public transport can hinder the mobility of low-income individuals in developing countries who have to “choose” between public transport and walking, as well as poorer people in developed countries, who are less likely to walk and have few public transport options. In early research, only the main transport mode was considered, but now, intermodal transfers are increasingly taken into account.

The second category, transport supply, also impacts modal choice. Public transport use is greater in large cities, especially in the most central area where public transport supply is the highest and car performance the lowest. Supply also has an influence on nonmotorized mode use.

Even if it is probably not the only reason, cycling is at its highest in the Netherlands and in Denmark, where cycling lane supply is also more developed. Supply level is important, but perceived quality of service also influences choice. Comfort, information, accessibility (especially for people with disabilities), and even image play important roles in travel mode choice. The built environment and urban form have also a direct impact on transport mode use. Low density generally favors car use, whereas high density encourages public transport use. The mix of urban land use functions (for example,

housing, job, shopping, etc.) and high integration between transport and land use allow the greater development of cycling and walking, as is seen in transit-oriented development.

Individual and household characteristics strongly impact mode usage. Gender, age, generation, activity status, and income are generally associated with differences in mode choice. Stage in life cycle appears also important; when individuals are moving from one stage to another appears to be the best period to encourage modal shift. These “objective” factors need to be combined with social perceptions and cultural and attitudinal factors associated with travel modes, because it appears that they could be strong forces to motivate behavioral change, as envisaged in travel demand management actions, for instance.

Conclusion

Considerable knowledge has been accumulated on determinants of travel mode. This knowledge is more and more used in order to propose new transport policies emphasizing the need to increase the use of more sustainable, safer, and more healthful transport modes. More local measures are also developing, such as company mobility plans or travel demand management programs. The need remains, however, to develop research to better understand the way mode use can change through transport policy, land use and built environment planning, or more personal changes. Also needed is longer-term planning, which implies continuing to develop models of interaction between transport and land use.

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See Also: Automobile Culture; Social Equity and Discrimination in Transportation; Travel Choice; Urban Sprawl Versus Compact Development.

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Travel by Persons

The mode of transport used by a person is dependent upon a complex set of often interdependent variables. Understanding the reasons behind particular choices of transport is important in providing an evidence base for the development of effective policies, transport strategies, and plans that will change current patterns of travel behavior in favor of more sustainable mobility.

According to the European Environment Agency (EEA), the impacts of transport are vast and significant. Transport in Europe accounts for over one-third of all final energy consumption and for one-fifth of greenhouse gas emissions. In addition, transport affects noise levels, urban air pollution, and concentrations of particulate matter, particularly in urban environments, and it often requires damage to the landscape for the purpose of roadways, runways, navigation, and the associated supporting infrastructure.

Other direct and indirect consequences of transport networks include the destruction of natural habitats (and sometimes whole ecosystems) in the new construction or improvements to existing road, rail, waterway, bike, and pedestrian routes. Detrimental effects on human health (for example, increased respiratory problems) and a reduction in overall plant life and crop yields can also result from high atmospheric pollution levels, to which transportation in its variety of forms contributes.

Nevertheless, travel is an integral component of everyday life. Many activities people want to engage in are separated by space, which requires people to travel. Traveling, and transport in its many forms, enables individuals to meet their needs and provides access to other people, locations, services, and opportunities.

Trips are made for a variety of reasons, including commuting to a place of work, sightseeing and tourism, for leisure purposes, and so-called maintenance trips, such as shopping, accessing health care facilities, and taking children to school. The

transportation choices people make in traveling are based upon their options, constraints, habits, and opportunities.

The amount traveled by individuals is increasing across the globe as modes of transport become ever more accessible. In the United Kingdom (UK), for example, the distances traveled each year by individuals has increased fourfold since the 1950s and 1960s. During the same period, total passenger miles traveled by car increased by over 900 percent, while rail has increased by 26 percent. Similarly, in the United States distances traveled rose by 155 percent between 1970 and 2010.

All other modes have declined, however, including bus travel (by 50 percent), cycling (by 83 percent), and walking. Little research work has been undertaken on travel behavior and modal choice in developing countries, where in many countries vehicle ownership is significantly lower and the need to travel may be offset by constraints in the individual's ability to travel.

In Europe, trips by car (as a driver or passenger) accounted for 64 percent of all trips made and 78 percent of distance traveled in 2010. The arguments for car use, including convenience, speed, comfort, and individual freedom, mean that in most industrialized countries the automobile is the most widely used mode of individual transport.

Travel Behavior

Understanding individual travel behavior, its driving forces, and its influences is important in order to be capable of changing behaviors. Behavioral change is necessary in the transport mode choices of individuals because of the environmental and human health implications of most people's current patterns of mobility.

To understand the factors that trigger certain transport mode choices, transport behavior research has emerged as a discipline. The purpose of transport behavior research is to identify the reasons and stimuli for transport choices through the gathering of data on aspects of an individual's or group's (often referred to as a "segmentation") travel behavior. This knowledge is then used to develop effective transport strategies and sustainable transport systems, which will create more sustainable patterns of travel by persons, or sustainable mobility.

In general, what is clear through transport behavior research is that the choice of mode of

transport depends upon interactions among individual factors such as attitudes and opportunities, and the accessibility of places and activities (that is, the distribution in space of the individuals and the infrastructure accessible to them). Research has concentrated until recently on the spatial-temporal context of transport mode and choice.

The attributes of travel behavior can be classified into four different groups: a land use component (locations and characteristics of opportunities and of demand), a transport component (location and characteristics of infrastructure for passenger and freight travel), a temporal component (opening hours of shops, available time for activities, etc.), and an individual component (for example, income, gender, educational level, mobility resources, and vehicle ownership).

The customary attributes identified and studied in travel behavior research include the spatial and urban structure, the availability and service of a transport system, economic factors, political and planning factors, and social and demographic factors. The most important sociodemographic variables influencing the mode of transport used by individuals include age, household composition, income, gender, and car ownership.

Cost is a primary driver of choice of transport mode, as is household composition and income. Key stages within the household life cycle that impact travel behaviors include gaining employment, having children, and retirement. Households with children have distinct travel behavior characteristics, including being highly dependent on cars as the primary source of travel mode.

The process of establishing habits, which is recognized as an influence of travel mode choice and mobility decisions taken by individuals, can be unfavorable to attempts at behavior change. On a day-to-day basis, people's travel mode choice is often habitual and not usually preceded by the deliberation of alternatives.

When a person's response to travel mode choice is a product of habit, it is known as automation. This automation or habitual character of individual travel behavior is the main reason for the common resistance of individual travel behavior to influencing measures; the automation intensifies the individual's focus on one chosen means of transport and reduces the perception of travel alternatives.

Psychological Factors

More recently, psychological factors, including perceptions, identity, social norms, and habit, are being used to understand travel mode choice. Likewise, psychosocial variables have been found to influence travel behavior.

One study looked into the significance of the car as a means of providing protection, autonomy, and prestige, as compared with public transport. Participants considered that they had greater protection from “undesirable” people with the use of automobiles and that private vehicles also provided autonomy, convenience, and greater access to a wider range of destinations than public transport.

Socially desirable attributes, such as competence, skill, and masculinity, were also perceived to be derived from car ownership. People who did not own cars were seen as eccentrics because of their nonconformity with what is perceived as the social norm. The recognition of the need to capture psychological factors in transport behavior research marks a departure from the theory of planned behavior, which is grounded in the belief that choice of travel mode is predominantly a reasoned decision related to attitudes, social norms, and perceived barriers to other forms of travel behavior.

Sociodemographic Segmentation

The *a priori* approach has been used almost exclusively in travel behavior research. With this approach, groups are selected from a population in advance, with the selection based upon known characteristics, usually such socioeconomic characteristics as income or gender. These groups of like-characteristics are known as segments. Sociodemographic segmentation is considered by some to be limited in what it can achieve because it does not take account of the more complex, statistically derived clusters of characteristics that are considered more representative of the population.

It has been argued that different people must be treated in different ways because they are motivated by different factors and are affected in different ways by policy. Thus, the customary segmentation based upon rationalist theoretical underpinning does not provide the framework upon which to understand the reasons for travel choice made by individuals.

One of the most dominant influences of travel choice for individuals is the built environment. This

holds true for industrialized and industrializing countries. This is widely recognized and has been demonstrated through a number of studies in different countries and different geographical areas. What is common to all, however, is that land use patterns influence travel behavior and the decision whether to use public transport, share a car, or drive alone.

The Australian Bureau of Statistics has identified that public transport use is considerably higher in capital cities than in other parts of Australia. This is a result of the more extensive and frequent public transport infrastructure available and accessible. These studies also show that those located in more rural areas and on urban fringes have the least sustainable travel behaviors, which is likely to pose greater challenges to policy makers in bringing forward sustainable travel systems.

Researchers in India identified that in densely populated areas of central Chennai, people were more likely to use nonmotorized modes of travel (walk or bicycle) than those on the periphery. They found that accessibility to transport modes is linked to the location of employment opportunities.

Higher residential density has been found to reduce solo-commuting (driver-only car commuting). Similarly, researchers have found that U.S. land use patterns reinforce vehicle dependence when they have compared suburban sprawl to areas with tighter urban planning and design controls in European countries. This research has led to more compact and higher-density urban forms, which leads, generally, to greater use of public transport or walking or cycling.

Another researcher concluded that location played a large part in the sustainability of travel behavior, with those living outside urban hubs and in rural areas using on average three times more fuel than those more centrally based in urban areas.

The environmental impact of the spatial influence of travel choice is greater for households in low-density and rural areas than those in very high-density areas, which produce approximately half the carbon dioxide emissions of their rural counterparts. Furthermore, when comparing the carbon footprint of automobile travel by individual households in rural and urban areas, more miles are traveled by rural households—approximately 8,000 vehicle miles traveled (VMT) annually compared to 4,000 VMT for those in urban areas.

For those in rural areas, fuel efficiency is dependent upon the nature, age, and size of the vehicle used. More fuel-efficient vehicles, then, can offset some of the increased carbon emissions resulting from the spatial dimension of travel and accessibility to transport alternatives, but this is dependent upon largely sociodemographic factors, particularly higher income.

In the UK, one of the Department for Transport's key environmental impact indicators for travel is the proportion of urban trips under five miles that people take either by walking, cycling, or public transport. However, it must be remembered in travel behavior research that people's ability to use alternative means of transport, whether for short or longer journeys, may be constrained by health, the lack of provision of facilities, or the temporal nature of that provision.

Qualitative Methods

The traditional approach to understanding travel by persons was to use quantitative methods of research. While this type of study methodological technique provides useful numeric data on those traveling, clarifying the who, what, where, and how, quantitative data are not predisposed to uncover the most critical question for transport policy development—the reasons for the mode of transport chosen. This is where qualitative methods have an increasingly important role to play in transport behavior research.

Qualitative methods facilitate understanding and provide insight into the complexities of travel behavior. Methods include focus groups, interviews, participant-observation techniques, and travel diaries (in which subjects capture details of all travel modes used within a particular time period).

These methods complement rather than annul quantitative approaches. In order to ensure quality of the data collected by way of qualitative research techniques, the techniques must be used with scientific rigor and grounded in theoretical frameworks. All empirical research into travel behavior and choice should be undertaken, as with any other research, to ensure high ethical standards, information, and protection for participants.

Conclusion

Travel behavior research is an evolving discipline. It grapples with highly complex issues that collectively determine an individual's choice of travel mode. Research in this field has recognized the

limitations of segmented research techniques and the greater intricacies of travel behavior; this will improve the evidence base for the creation of sustainable travel behavior.

Travel by individuals is mainly undertaken by automobile, but this depends upon a host of variables, including infrastructural, socioeconomic, demographic, and psychological factors. Factors affecting the embrace of alternate transport modes include a lack of awareness. This issue can be easily overcome with awareness campaigns and other soft transport policy initiatives.

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See Also: Transportation Studies; Travel by Households; Travel by Mode; Travel Choice; Travel Demand; Travel Diaries.

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Travel Choice

Travel choice refers to understanding how people make choices regarding their travel plans. This includes how much they travel, for what purposes, where, at what times, and by which mode. Another aspect asks how people make such decisions for the transport of commodities.

As a field, travel choice deals with theoretical constructs, behavioral assumptions, and methodologies for the analysis, representation, and inference of the way travelers behave and the interrelationships of this behavior with their activities, land use, and the transportation system. The understanding of these various aspects requires an interdisciplinary inquiry, engaging geography, engineering, statistics, urban and regional studies, economy, psychology, and sociology.

While the basic travel technology, the car, has changed relatively slowly, many other factors induce significant changes in travel behavior. In modern life, there is more leisure time and more engagement in nonwork out-of-home activities.

Work hours have become more flexible and more women are in the labor market. Information and communication technologies provide travelers with better information and enable substitute travel for all purposes. Work trips are no longer predominant, because there are more trips for shopping, social, and leisure purposes; trip chaining is more frequent; and traffic peaks are smoother.

These changes made household travel patterns more complicated by significantly increasing the number of alternative activity and travel patterns available to households. The relaxation of some constraints, such as the need to commute at fixed hours, provides more freedom and more alternatives, thus making the analysis of travel choices more complicated. At the same time, these changes significantly increase congestion and air pollution from motor vehicles, raising as a result the need to develop new objectives of policy and planning toward sustainable transportation.

The growing complexity in travel patterns and the need to estimate changes in travel choice in response to new policies have called for a better understanding of travel behavior. This includes issues such as how travel behavior is affected by new information and communication technologies, how land use and growth management affect travel behavior, and how travelers respond to auto restraint policies.

Understanding such effects is essential for a better design of new policies. In this regard, travel behavior lies at the core of procedures for the analysis and evaluation of transportation-related measures aimed at improving urban mobility, environmental quality, and a wide variety of social objectives.

Historically, the field has changed over time parallel to changes in transportation systems, planning goals, and travel behavior. In the 1960s, the development of the American interstate highway system led to the development of an operational macro-level system of models providing planners and engineers with travel demand forecasting tools.

This system, also known as the four-step process, relies on statistical tools and enables the forecast of various travel choice elements in an aggregate manner given the land use structure and socioeconomic characteristics of the population. In the late 1960s, additional emphasis was given to economic approaches motivated by the need to better understand travel behavior and to derive a value of behavioral travel time saving for cost-benefit analysis.

In the 1970s, the economic theory of the allocation and valuation of time developed toward an econometric approach providing a framework for modeling travel behavior. This approach was based on random utility modeling (RUM).

Thereafter, a growing interest in and the need to better understand the motives for travel behavior prompted the involvement of psychology, among other social sciences. Some of these studies questioned whether the RUM paradigm could accurately represent the set of decisions travelers use. That led to the development of the rules-based paradigm as an alternative method. In both approaches there is a move toward an activity-based framework in which there is an effort to understand travel behavior as derived from activity participation and time-use behavior.

Qualitative data on travel behavior, collected by various types of travel surveys, is an essential element to all these efforts. The most common surveys are travel habit surveys, where respondents are asked to report details about all their trips within a given time period, usually at least 24 hours. Stated-preference data, in which people are asked to indicate their choice among various alternatives under some hypothetical scenarios, are used to estimate travel choices for new modes or policies that do not currently exist.

State and regional transportation planning organizations use travel demand models to forecast people's travel choices and their impact on the transportation systems. The four-step model mentioned above is still the most common model used for this purpose. This is mostly an aggregate model where



Travel choices can sometimes be made for social reasons as well as economic reasons. An important role of optional modes of transportation is ensuring that all members of society are able to travel, not just those with a driver's license and access to an automobile. Rail travel, for instance, offers transport at an economy of scale not available through private transport.

the four steps represent the main travel choices people make: how much to travel (trip generation), where to travel or how these trips are distributed in space (trip distribution), which modes are they using (mode choice), and which routes, either high-way routes or public transportation routes, they are using (traffic or public transport assignment). A fifth step—time of day—is usually added to represent the choice of time of day in which these trips are conducted.

Policy makers are most interested in the mode choice people make, trying to design policies to encourage people to shift from automobile modes to public transport and nonmotorized modes. Accordingly, even within this aggregate framework, many of the mode choice models are estimated as disaggregate models to better understand individual mode choice.

Some transportation planning organizations have already developed fully disaggregate travel demand choice models based on the activity-based paradigm that can better analyze travel behavior and response to policies.

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See Also: Activity-Based Models; Freight Transport Models; Mode Choice Models; Mode Share/Mode Choice; Travel by Households; Travel by Mode; Travel Demand.

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Travel Demand

Travel demand generally refers to the movement of goods and people, that is, activities people do over space. Travel demand can be defined from many different perspectives. Some quantifiable measures of travel demand are the following:

- *Frequency of trips*: How many trips does one person make?
- *Trip length*: How far is the trip?
- *Mode*: What transportation mode(s) does the person use? Walking, bicycling, car or transit, or a combination of all?
- *Purpose*: why does the person want to make the trip? Why not stay at home and telecommute?
- *Sequence*: What is the pattern of trips? Is this a chained trip?
- *Path*: Which route does the person choose? Who accompanies whom?
- *Departure time*: When is the trip made? Is the departure time flexible?
- *Duration*: How long will the trip last?
- *Cost*: How much money or equivalent time spent is on the trip?

Factors Influencing Travel Demand

Individuals' travel demand can be directly influenced by many factors, with demographic trends, economic activities, land use patterns, and transportation facilities being among the most influential. Studies on the impacts of land use on travel demand can be traced to the 1970s. Researchers P. G. Newman and J. R. Kenworthy compared population density and gasoline consumption in several metropolitan areas and concluded that gasoline consumption decreased with higher density. The study's results were taken up by proponents of the new urbanism movement and neotraditional designs in the 1990s who argued for more intense development patterns.

Later studies have analyzed the relationship between the built environment and travel demand looking at different aspects of travel demand, including vehicle miles traveled (VMT), travel mode, and trip frequency. These studies also found that households in higher density neighborhoods tend to own fewer vehicles and that households owning fewer cars tend to use transit more and generate fewer VMT.

Transportation facilities are expected to play an influential role: factors related to transportation infrastructure include roadway conditions (such as scale, network connectivity, operational strategies and pavement conditions), walking and cycling conditions, and transit service. The combination of transit service with other strategies, such as transit-oriented development (TOD), has been found to cause noticeable changes in travel mode (more reliance on transit) and length (shorter trips).

Traditional studies mainly focus on population density and demographic characteristics without placing them into a spatial context. However, the centeredness and distribution pattern is often the real determining factor of residents' travel demand. Compared to uniformly distributed populations, clustered populations tend to have shorter and less frequent trips. Recent studies have resorted to spatial statistics to quantify the spatial patterns of demographics.

A major part of travel demand comes from economic activities such as working, shopping, and entertaining. The pattern of economic activities is often evaluated by an accessibility index, which captures the interaction between the location of interest and the economic entities in its neighboring areas. For example, the employment accessibility index, often calculated as the weighted (by inverse of distance) summation of surrounding employment is normally found to be negatively correlated with commuting trip distance.

A rational person will choose the way of travel that maximizes his or her own utility. People have different utility functions and preferences, which affect their travel decisions, leading to observable heterogeneity in travel demand. Aggregate analysis often neglects such heterogeneity in travel demand forecasting, leading to results that indicate insensitivity to policy change. Recognizing this problem, more sophisticated travel demand analysis today often relies on disaggregate approaches.

Public policy can have great influence on travel demand. For example, some cities have experimented with closing certain areas to traffic or charging a fee for entrance, or implementing “odd-even” traffic restrictions, in order to control travel demand.

Estimation Methods

There are generally four types of approaches used for estimating travel demand, with increasing data requirements and estimation accuracy: growth factor, land use trip rates, cross-classification, and regression models.

Growth factor methods assume uniform growth rates relative to the base year. The number of future trips equals the product of the growth factor and the base year travel demand, where the growth factor is often determined by the demographic features in the base year and future year. Growth factor models are easy to understand and relatively reliable for short-term forecasting. However, they require travel demand data for the base year and do not account for changes in land use or any other key facilities.

As the name suggests, the land use trip rates method estimates travel demand based on trip rates generated by specific types of land use and the total amount of that land use type, indicated by variables such as total area of establishment. The Institution of Transportation Engineers (ITE) Trip Generation Manual provides complete guidelines on this method. The land use trip rates method is popularly used in traffic impact analysis for specific land development projects and long-term planning for small cities. This method is also easy to use and easy to interpret, with low data requirements. However, as this method does not incorporate any behavioral or social-economic information, its explanatory power is often low.

Cross-classification can be considered a more sophisticated version of the trip rates method, as it first determines trip rates as a function of socioeconomic attributes (often at household level). Typical socioeconomic variables used include household income, car ownership, and family structure. Cross classification is more flexible than trip rates in that it better accommodates heterogeneity. It does not rely on information about the zoning system and does not require any assumptions regarding dependent and independent variables.

However, this method requires much larger sample sizes to achieve reliable estimates. It does

not allow for extrapolation beyond the calibration data and there is no efficient way to identify the best variables.

The development of econometric models in the last several decades has enabled more sophisticated estimation of travel demand. Many types of models have been developed to address the different aspects of travel demand. For instance, linear models are often used to estimate total demand at the zonal level; count data models can be used to estimate travel frequency at the individual or household level; discrete choice models are used for estimating mode choice; hazard models can be used to estimate the duration of a trip. Depending on the data characteristics and the probability functions, different models can be derived.

Compared to the previous methods, regression models are more behaviorally consistent, statistically more rigorous, allow for selection of independent variables, and have better explanatory and predictive powers. The downside of regression models includes their high data requirements, the accuracy of model estimates, and the need for careful interpretation of results.

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See Also: Transit Planning, International;
Transportation Planning; Travel Demand Forecasting.

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Travel Demand Forecasting

Federal law in the United States mandates that state and metropolitan planning organizations must develop transportation plans and programs to accommodate the mobility requirements of people and goods within their regional boundaries. Travel demand forecasting is an integral tool used to help transportation planning organizations and other key constituents in government and industry estimate future travel demand and assess the associated financial, social, and environmental impacts of various transportation scenarios.

The findings from the forecasting process are used to help establish transportation policies, facilitate transportation planning, and enable informed decisions pertaining to transportation infrastructure, usage, and impacts.

Conventional travel demand forecasting covers a broad array of considerations and activities that address various transportation types and systems, time frames, geographies, regulatory and policy issues, and needs of key stakeholder groups. Forecasting models typically follow a four-step process aimed at reasonably estimating travel volumes and implications associated with specific types of transportation infrastructure, such as roadways and bridges, rail lines, airports and water ports, occurring at a given period of time, such as during rush hour, weekends, or over the life span of the transport mechanism. Travel demand forecasting models may also incorporate specific considerations tied to air quality standards, land use patterns, safety issues, pricing options, commercial repercussions, and other factors.

The Forecasting Process

The base unit of measurement in traditional travel demand forecasting models is called the trip, defined as an individual or vehicle traveling from a point of origin to a point of destination without

making intermediate stops along the way. Each trip is further defined by the purpose behind the trip, such as work- or non-work-related travel, and is shaped in part by data availability, planning needs, and regional characteristics.

The first step in the travel demand forecasting process focuses on trip generation. Modeling at this stage seeks to estimate the number of trips of each type that start or terminate in each location based on the amount of activity in the area being analyzed, sometimes referred to as the traffic analysis zone. The trip type is generally broken down into three broad categories: vehicle trips; person trips by motorized means such as automobile and transit; or person trips by any means, which can include motorized as well as nonmotorized modes such as bicycling or walking.

Trip generation models also may account for household variables linked to trip-making behavior. These variables may include the number of household inhabitants overall, the number of workers within a household and their employment type, the total income level of a household, and the availability of and access to vehicles among members of the household.

The second step in travel demand forecasting addresses trip distribution, which seeks to quantify the volume of trips traveling between specific traffic analysis zones. In some cases, travel demand forecasting models may assess travel qualities and behaviors occurring outside the traffic analysis zone. The trip distribution step in the modeling process incorporates variables related to cost parameters associated with travel between zones. Trip distribution variables also consider the amount of trip-making activity in both the originating zone and the ultimate destination zone.

After trip distribution is modeled, forecasters focus on a step known as mode choice. This third step involves dividing the trip distribution results into trips categorized by travel mode. The mode definitions vary based on the types of transportation options available in traffic analysis zones and by the types of planning analyses needed.

The mode definitions are typically grouped into automobile modes, transit modes, and nonmotorized modes. Automobile modes are most often defined by occupancy levels of a vehicle, while transit modes encompass access and service types such as personal automobile, express bus, commuter rail,

and other transport options. Nonmotorized modes include walking and bike riding activities as part of the forecasting model.

The fourth and final stage of the traditional travel demand forecasting process is trip assignment, which includes distinct highway and transit assignment components. The highway assignment process maps vehicle trips from the origin-destination models created earlier in the forecasting process onto paths along the highway network to assess traffic volumes by time of day and vehicle type. Adding variables related to vehicle speed and expected travel times helps indicate levels of traffic congestion at various points along the network links. The transit assignment process maps trips from the prior transit trip models onto individual transit routes and links to provide data about specific transit line volumes and usage, such as station stops, boardings, and departures.

Sometimes a separate step known as time-of-day modeling is used as part of the travel demand forecasting process as a way to further differentiate daily trips into specific time periods, such as morning and late afternoon peak periods, midday, and evening off-peak periods. This supporting step may be applied at any time between the trip generation and trip assignment stages of the conventional travel demand forecasting process.

Emerging Approaches

Increasingly advanced approaches to modeling have emerged over the years as the expectations and requirements of travel demand forecasting have expanded to accommodate evolving regulatory and market-based needs. Among the newer techniques and parameters being utilized are activity-based models, dynamic traffic assignment models, and traffic simulation models.

Unlike the traditional travel demand forecasting process that views travel participation primarily as a trip, activity-based models consider travel to be a demand that is driven by the need to pursue activities. In essence, activity-based forecasting treats travel as a means to an end rather than conventional modeling that treats it as an end in itself. Underlying the activity-based approach is a desire to better understand the behavioral rationale behind individual decisions leading to participation in certain activities in specific places at particular times. Those factors serve as the basis for travel

needs and practices according to the activity-based theory. Among the factors considered in this type of forecasting model are the needs, preferences, and habits of individuals and groups; the cultural and social norms of the relevant community; and the travel service options available within the surrounding environment.

Activity-based modeling uses tours rather than trips as the basic unit to represent travel patterns. Tours are defined as chains of trips that start and end at the same location, like home or the office. Focusing on tours helps illuminate consistencies/inconsistencies as well as interdependencies within the behavioral attributes and travel activities comprising a single tour. In the traditional trip-based approach, each trip is considered to be independent from other trips, making it difficult to connect potentially important relationships within the modeling data.

The dynamic traffic assignment model aims to predict traffic flow conditions under various sociodemographic, land use, and service capacity circumstances. Traffic flow conditions result from the interactions between travel demand at an individual level and travel types and service capacity provided by the transportation system. In this model, activity-based travel patterns are put into traffic assignments based on specified levels of service and capacity. A repetitive feedback process is employed to ensure accurate consideration of dynamic supply and demand interactions tied to activity-based travel behaviors and consequential traffic flow conditions.

Most dynamic traffic assignment models are supported by a traffic simulation model that replicates the expected movement of traffic using defined network parameters linked with spatial pathway projections and travel time estimates. This approach offers forecasters the ability to address time-dependent traffic conditions across the traffic network with greater spatial accuracy than traditional traffic assignment models, thus enabling more accurate estimation of the effects of traffic controls and technologies. Similar forecasting models are available to support transit passenger simulations.

Depending on the distinct transportation issue under evaluation, the specific travel demand forecasting model utilized will vary in its underlying process and structure, in the parameters included for consideration, and in the scope and complexity of analysis. Regardless of the approach selected, the

intent of any travel demand forecasting effort is to create relevant models with accurate data that can be used to identify needs and inform transportation planning decisions.

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See Also: Activity-Based Models; Airport Planning; Harbor and Port Planning; Highway Planning; Integrated Transportation and Urban Land Use Planning Models; Metropolitan Planning Organizations; Regional Transportation Planning; State Transportation Planning; Traffic Forecasts; Travel Modeling.

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Travel Destinations

Travel destination is one of the numerous areas of travel examined by travel researchers, and is often best understood in the context of other travel decisions, such as the mode of transport, the route choices, who accompanies the traveler, and the purpose of the trip itself.

In particular, travel destination is often looked at in the context of vacations and other recreational and social travel and why travelers make the choices they make. The better researchers understand these choices and decision-making mechanisms, the better they can forecast traffic and the economic and environmental impacts of travel, by creating more accurate transportation planning models and simulations. Such models depend on high-quality data sets, of course.

The Federal Highway Administration, in the U.S. Department of Transportation, administers the

National Household Travel Survey (preceded from 1969 to 1995 by the National Personal Transportation Survey) at irregular intervals (most recently 2001 and 2009) to collect information on Americans' travel choices, transport mode usage, and travel miles. However, in the area of examining destination choice and recreational travel, the data are not as useful as they are in looking at commuting behaviors and other matters more directly relevant to federal transportation policy. Travel diaries, on the other hand, can be very useful when researchers are able to interest enough participants in maintaining them.

Travel behavior and selection of destinations is widely hypothesized by researchers to be influenced by self-congruity: the congruity between a tourist's self-concept and the destination visitor image. This is as important as, and believed to influence, functional congruity, which is the congruity between the useful aspects (or "good points") about a travel destination and the tourist's ideal expectations of those aspects. The environment of the destination itself also affects the destination visitor image and the tourist's perception of the destination's good points.

Destination image is, of course, also key—the beliefs and awareness that an individual has about the destination, including knowledge, actual experiences, perceptions, and emotions. Destination image is informed by numerous factors, including indirect and direct experiences, the portrayal of a destination in pop culture, news coverage, encounters with people from the destination, and so on. Numerous studies since the 1970s have shown the ways that destination image influences tourist choices, and travel decision-making models have reflected this. C. Gunn's model of seven phases of the travel experience depends heavily on the importance of destination image:

1. The traveler creates mental images about vacation experiences based on various sources of information. This destination image is the organic image, based mainly on sources of information like social contacts, learning from school, pop culture depictions, and the news.
2. Those images are modified by further information specific to travel and tourist activities, such as those prepared

commercially for and by travel agents. In the model, this is called the induced image.

3. The traveler decides to take a trip to the destination.
4. The trip occurs.
5. The traveler has experiences at the destination.
6. The traveler returns home.
7. The traveler's mental images are modified in accordance with his experience.

The first, second, and last phases are states of destination image formation, the first two using secondary sources of information, and the last using firsthand experience.

Travel satisfaction depends in part on how the travel experience, the experience of the destination, compares to expectation, especially the value of expected positive experiences. Various researchers have suggested models for measuring destination image and satisfaction, based on rating a number of attributes according to a scale, and comparing the scores (some models weight the attributes) of the destination image with the destination experience.

For instance, P. L. Pearce's model proposed in 1982 uses 13 attributes on a six-point scale. J. L. Crompton's 1979 model uses 30 attributes on a seven-point scale. A. Phelps's 1986 model uses 32 attributes in a simple yes/no checklist. Other models that use unstructured open-ended questions to interrogate the traveler do not provide a methodology for generating a quantitative score.

Destination characteristics may be separated into categories like functional (the climate, the costs of expenses) versus psychological (the friendliness of the people encountered), or common (the hotel had HBO) versus unique (the hotel was *Star Wars*-themed). Typical characteristics discussed in surveys interrogating destination image include scenery and natural attractions, costs and fairness of costs, climate, tourist activities and attractions, nightlife, sports facilities or activities, national parks and wilderness activities, local infrastructure and transportation, architecture, historic sites and museums, beaches, shopping, special accommodations, cities, fairs, exhibits, festivals, tours, crowdedness, cleanliness, perceptions of safety, economic development and affluence, urbanization, commercialization, political stability, hospitality and



Visitors to Las Vegas, Nevada, take a gondola ride under an artificial sky in an indoor shopping mall at the Venetian Hotel in 2011. Studies have found that in selecting destinations, travelers are influenced by combinations of novelty-seeking and familiar-seeking, and cultural proximity has an influence on satisfaction.

friendliness, differences in customs and culture, differences in cuisine, restfulness, atmosphere (which can be described qualitatively as well as rated quantitatively), opportunity for adventure, opportunity for learning, family oriented versus adult oriented, and fame or reputation.

At least one recent study has suggested that "cultural proximity" is a factor in destination image as well, with the destination image of a given destination improving if the tourist feels it represents a culture similar to his or her own. Some studies have attempted to have tourists describe destinations in terms of personality traits, as has been done with brand personality studies, but only a handful of 21st-century studies have demonstrated tourists' ability to do so. Often it seems to be easier for

tourists to do so when the destination is one with extensive exposure in pop culture and the popular imagination.

Researchers Ahmet Usakli and Seyhmus Baloglu's 2011 study on self-congruity, for instance, found that in a sampling of 368 visitors to Las Vegas, a consensus developed that Las Vegas can be described as "vibrant, sophisticated, competent, contemporary, and sincere," at least some of which invokes personality descriptors not often applied to places.

Self-concept in general is important in consumer choices, and self-congruity theory was originally proposed in reference to brand perceptions and satisfaction but applied to tourism in 1992. The impact of cultural proximity on travel satisfaction is an example of the ways self-concept impinges on travel experience. To oversimplify somewhat, people's experience of travel is influenced by what they believe that travel says about them and how they feel about what it says about them.

As with destination image, self-congruity can be considered in both functional and psychological or symbolic categories. A number of studies have found that in selecting destinations, potential travelers—especially if cost is not a concern, such as in hypothetical "dream vacation" surveys—select destinations that externalize their self-image. The congruity of self and destination has been found to have a determining impact on whether the traveler makes a return trip, but interestingly, it has no perceptible impact on whether the traveler recommends the destination to others.

Another motive for selecting a destination is what behavior psychologists call novelty seeking. Novelty seeking is part of the complex equation behind the traveler's decision-making process, which weighs risks and rewards. While any new experience carries a risk of unpleasantness, mediocrity, or boredom, the idea of novelty seeking as a motive assigns a value to newness itself: independent of the value of the satisfaction and enjoyment the experience may eventually bring, the fact that it is new gives it a perceived value in the decision-making stage. People are also motivated by familiar-seeking, though—the desire to have experiences that comfort by being similar to experiences we have previously enjoyed.

The combination of novelty seeking and familiar seeking as motives, with cultural proximity as an influence on satisfaction, suggests destinations like

near neighbors—Mexico, for instance, for Americans, or simply other American cities with especially overt personalities like Las Vegas, New York, and New Orleans. Of course, the extent to which an individual is motivated by novelty seeking or familiar seeking varies greatly from person to person, as does one's openness to new experiences and the unknown.

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See Also: Automobile Travel Patterns; Destination Choice Models; National Household Travel Survey; Noncommuter Travel; Recreational Travel; Travel by Households; Travel by Persons; Travel Choice; Travel Diaries; Travel Patterns by Income; Travel Patterns of the Elderly.

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Travel Diaries

Travel diaries have been adopted relatively recently as a considerably more advanced method to collect trip information over a 24-hour period. In travel diary surveys, randomly selected participants are asked to personally record information about each trip that they make during a one-day to one-week period.

Participants of travel-diary surveys record trip origin, destination, time, mode, and other characteristics into their travel diaries. The earliest travel diary studies used paper-and-pencil techniques, which resulted in errors resulting from omissions of trips or trip elements, language issues, illegible handwriting, and key entry errors. The paper-and-pencil method has been replaced with computer-assisted telephone-interviews, which use specialized software to call survey respondents.

Travel diaries have taken three main forms: trip based, place based, and activity based. In the trip-based diary, respondents are asked to report each origin-to-destination movement that they undertook over a daily period, without explicitly requiring the respondent to report trips in chronological order.

Activity-based diaries ask respondents to list the activities they did and follow up by asking how the respondent traveled to the place where this activity occurred. In this survey type, the recall of activity participation is requested in chronological order for the entire diary period.

The place-based diary is a hybrid of a trip-based and an activity-based diary, in which respondents are asked which places they went in chronological sequence across the diary period and are then asked how they got there. The place-based diary attempts to align the respondents' recall process to a more intuitive way of thinking about and recalling daily travel.

Examples

An example of a travel-diary survey is the project called Mobidrive. Mobidrive conducted a six-week continuous travel-diary study with the aim to analyze the rhythms in the behavior of the respondents. The travel-diary survey took place in two German cities of about 300,000 inhabitants each, where a total of 317 persons in 139 households participated in the main study.

A second travel-diary survey example, the Portland Travel and Activity Survey in Oregon, was designed to collect information about where people travel for work, school, shopping, and other purposes to identify and prioritize transportation needs. Survey results provided the foundation to plan the construction of future roads, bridges, sidewalks or bike routes, and changes in transit services, as well as to plan other projects affecting mobility, access to jobs, air quality, and quality of life. In total, 2,747 households were recruited to participate in the study and 1,951 provided travel data.

A third example, the Victorian Integrated Survey of Travel and Activity in Victoria, Australia, is a comprehensive travel-diary survey of how, where, and why Victorians travel. The survey was used to help understand the impacts of changes in transport infrastructure, population growth, and the broader transport and land use planning environment. With a sample size of 17,100 households (43,800 people), respondents were asked to fill in a travel diary for one specified day of the year.

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See Also: Transportation Statistics and Databases; Transportation Surveys; Travel by Households; Travel by Mode; Travel Demand; Travel Surveys.

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Travel Model Calibration and Validation

Travel model calibration is a series of formulae used in transportation forecasting that estimates the number of pedestrians or vehicles that will travel through a particular destination or road. Travel model calibration is the method used to make models reproduce what a snapshot of data has shown.

Forecasters evaluate current traffic data and base it against factors such as population predictions, employment, and current events to develop such models. Calibration specifically refers to the adjustments of constants and parameters within estimated models to reflect the data previously collected. This, however, is not to be confused with model validation. Validation is the application of the calibrated model and comparing those results against observed data. For example, the calibration data may be data collected in a given year, while the validation data may have been collected from a different year and used to compare against the current year.

Travel model calibration and trip forecasting is important for transportation policy, planning, and engineering. Such data can reveal how large or small infrastructure should be, estimate necessary funding, anticipate social demands, and evaluate environmental impacts.

The Right Data

There are several sources of data that travel models rely upon, including accurate estimates of base year traffic analysis zone (TAZ) household characteristics and employment information, representation of the base-year highway and transit network, a base-year travel survey, and base-year ground counts.

Travel model calibrations are based on socioeconomic and transportation network data.

Socioeconomic data is typically derived from the U.S. Census or American Community Survey and identifies qualities about travelers and pedestrians such as populations, age, race, gender, income, professional industry, place of employment, vehicle ownership, annual income, and rent or mortgage details.

Over time, socioeconomic data becomes unpredictable because of the ever-changing factors that influence it. Transportation network data is considered to be more predictable in this regard. Many models are already in place and simply need updating over time.

The models already in place can serve as validation, and therefore the problem of relying on the same data used to develop the model does not occur. Transportation network data can include topologically integrated geographic encoding and referencing files, commerce vendors, aerial photography, transit route maps and schedules, and transit operation studies.

Two prongs of data represent the first steps in designing a model to forecast travel predictions on a particular road or region. Therefore, reliable predictions depend upon reliable current information and forecasts of both socioeconomic and transportation network data.

In addition to transportation network data, trip distribution data is necessary. Trip length frequency distribution is available as a part of the trip-distribution model set. Information needed for this data includes the average length of a trip and the maximum length of a trip.

The zone radii, or centroid distance parameter, measures the distance in minutes of travel time from the center point of the zone centroid to the nearest point on the perimeter of the zone. Finally, bias factors, such as social and economic factors, impact data. Models take into consideration bias factors when determining validity.

Designing the Model

The significance of designing a proper model and validating its results cannot be understated. The model must yield accurate results to properly gauge driver behavior and traffic performance characteristics.

When designing a travel model, the initial steps are considered the trial-and-error period when the parameters are set by the most reliable

data. Observed data is taken from previously collected travel pattern surveys, which is transportation network data in use. These models can also be completed by using constants and parameters that have been developed for another road or region that is similar to the one in question. This is referred to as “importing.”

One strategy performs calibration in three steps: calibrate capacity at key bottlenecks, traffic volumes, and system performance. Calibrating capacity at key bottlenecks studies areas of high congestion that could lead to delays or long lines. Balancing the designed model against this data will help analysts decide if the plan will meet the high capacity of these target areas or if the parameters must be adjusted.

When calibrating traffic volumes, it is important to be mindful of areas that have multiple routes to different destinations, which may skew data. System performance includes measuring for speed, density, travel time, delay, and queues that are unique to local conditions.

After the models have been developed, they are validated to ensure that they sufficiently perform and reveal data that is intended to properly estimate traffic volumes. This establishes credibility of the model. The models are then compared against traffic counts, such as transit ridership against specific parameters within the area being measured. Such parameters are referred to as screenlines, cutlines, or cordon lines. These lines typically surround a particular area of interest, such as a central business district or a shopping district. Using assumed data against the models is called model sensitivity testing, which determines if the model results are plausible.

It should be noted, however, that no data will ever be entirely accurate. Situations that influence traffic patterns, such as special events, natural disasters, economic downturn, and personal behavior will always alter results, for which all variables cannot be controlled.

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See Also: Highway Planning; Traffic Studies and Surveys; Transit Planning, International; Transportation Improvement Programs; Transportation Planning; Travel Modeling.

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Travel Model Improvement Program

Established in 1994, the Travel Model Improvement Program (TMIP) is a program managed by the Federal Highway Administration (FHWA), Federal Transit Administration (FTA), Office of the Secretary of Transportation, and Environmental Protection Agency (EPA). TMIP is administered by the Volpe National Transportation Systems Center (VNTSC).

Mission and Goals

The TMIP’s mission is to support effective use of analytic methods and tools in transportation decision making. It has set the following three goals centering around transportation research, technical training, and technology transfer:

1. To develop and improve analytical methods in response to the increasing demands of planning and environmental decision-making processes mandated by the Clean Air Act Amendments (CAAA) of 1990 and Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, to better reflect today's lifestyles and travel behavior, and to provide information needed to answer questions confronting today's transportation policy makers
2. To help planning agencies build their institutional capacity to develop and deliver travel data and analyses
3. To support best practices in applying analytical tools to transportation planning decision making

The TMIP is organized into four activity tracks, which are improving current models for near-term use, developing entirely new models in the longer term, improving data collection for travel forecasting, and providing technical training and assistance to help transportation planners improve their models and skills.

Program Guidance and Community

Program guidance is provided by a peer-review panel comprised of experts from the principal audiences of program results. That panel identifies a broad agenda of research needs for the program.

In addition, the Peer Review Program provides an opportunity for planning agencies to invite an expert peer-review panel to review their data, methods, tools, and planning models to ensure that the technical processes they are applying meet the agencies' analysis needs. The TMIP supports peer reviews by assisting agencies in panel assembly, logistics, funding for travel, and, most important, documenting the peer-review meetings and preparing a final report that summarizes the review for the host agency.

Examples of the peer reviews conducted include the Sacramento Area Council of Governments transportation analysis simulation system (TRANSIMS) in November 2009, the Omaha–Council Bluffs Area Planning Agency in November 2010, the Detroit-TRANSIMS in March 2010, the Mid-Ohio Regional Planning Commission TRANSIMS in December 2010, the Association of Monterey

Bay Area Governments in April 2011, the New York Metropolitan Transportation Commission in April 2011, and the Chattanooga–Hamilton County RPC in May 2011.

The TMIP has made a number of technologies and services available to provide interactive learning and improve communication among transportation professionals. The TMIP community resources facilitate TMIP's outreach and capacity-building goals, foster creativity, encourage knowledge sharing, and further strengthen the state of practice in travel analysis methods. The primary resources that make up the TMIP community include TMIP-L E-mail List, Webinars, and Ask the Modeling Experts.

Accomplishments

Since its inception, the TMIP has supported research promoting development of the TRANSIMS, TELUS, UrbanSim, and MOVES software. It has also supported more than 30 peer reviews at state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) around the country. It has provided technical training and hosted National Highway Institute (NHI) training courses, created and maintained a Web Knowledge and Information Exchange (WKIE), and sponsored research leading to hundreds of published reports.

The TMIP has also partnered with important industry organizations including the Association of Metropolitan Planning Organizations (AMPO), American Association of State Highway and Transportation Officials (AASHTO), Transportation Research Board (TRB), and National Association of Regional Councils (NARC).

TMIP Resources

The TMIP maintains a set of recommended reading materials for the transportation industry. It also develops and delivers seminars, Web seminars (Webinars), and workshops on all aspects of transportation analysis, modeling, and simulation. The TMIP also serves as technical contact for some of the National Highway Institute travel-modeling-related courses. The TMIP also maintains a Web site that provides the modeling community updates on relevant news, tools, and upcoming conferences.

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See Also: Freight Transport Models; Metropolitan Planning Organizations; State Transportation Planning; Transportation Planning; Travel Modeling; Urban Transportation Modeling System.

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Travel Modeling

In the mathematical sense, a model is a description of a system using mathematical concepts and language. This same term could also be described as a mathematical account of something in the real world. Researchers most often use models for the purpose of quantifying real-world systems toward the goal of understanding those systems. Traffic researchers use travel models (also known as travel simulations) for the purpose of forecasting future trends and planning needed improvements.

A number of questions are posed to planners that travel modeling can be useful in solving; these include (but are not limited to) determining the impacts of fee policies in public transit systems, the influence of telecommunications and e-commerce on passenger and freight travel, and the impact of planning on land use and (conversely) the impact of terrain on planning, as well as methods through which the human impact on global climate change may be minimized through proper planning.

Travel modeling may take into account either specifically travel-related data or other regional factors. Travel variables frequently taken into consideration include the number of vehicles on a road, ridership of a railway line, the number of

passengers visiting an airport, or ships using a seaport. Other regional social-oriented factors that could be used in travel models include regional populations, employment rates, and the financial cost of travel.

Travel modeling is critical not only in developing transportation policy, planning public works, and determining the viability of a wide scope of projects but also in determining the social impact and environmental impact of proposed projects. By using travel modeling and associated computational methods, transportation researchers study traveler behavior, the impact of telecommunications on travel behavior, potential trends in transportation demand, and those elements of urban planning that could impact transportation systems.

The past decade has seen a number of changes in the field of travel modeling. These changes include the use of technology toward collecting data on traveler activity, the increased use of disaggregated microsimulations in understanding travel and associated activities on the individual level, and the increased use of dynamic network modeling.

Types

There are a variety of travel models available to transportation researchers. Two of the most commonly used model types are activity-based models and four-step models.

Activity-based models are designed to predict travel trends based on activity on the individual level. Such activities include the behavior of individuals, such as work, leisure, or shopping. The most commonly and successfully deployed model in the United States is the four-step model (or the urban transportation planning process). These models were first deployed in Detroit and Chicago in the 1950s.

In preparation for the process, land use forecasting must be computed. This forecasting includes predictions for the region in question as a whole, and may take into consideration factors such as population growth and concurrent public works projects. This forecasting can include any number of statistical tools, such as single-variable and multivariable regression analysis. Once the process has actually started, the four steps flow in sequential order. They are trip generation, trip distribution, mode choice, and route assignment.

The four-step model starts with trip generation. At this stage, the researcher composing the travel model must make some decisions regarding the variables he or she is studying. Among other factors, the researcher must categorize trips by purpose and the region served by zones. If the model is to be reliable and valid, it must take into account variables such as the terrain of the land, the demographics of the region, and other socioeconomic factors. After these decisions are made, analysts are able to attempt to determine either the frequency of trip origins or the destination of trips in each zone.

The next step of the four-step model is trip distribution. In this stage, researchers attempt to match traveler origins with their destinations. Researchers usually accomplish this task with complex trip tables. With these tables, researchers display travel trends between the various zones within the entire system studied. Historically, this is the least developed stage of the four-step model.

The next step in the four-step model is mode choice. In this research phase, researchers determine through complex computations the proportion of trips between each point of traveler origin and their destination points. These are typically divided into categories based on transportation mode, such as cars, trains, or walking.

The final step to the four-step model is route assignment. In this stage, the researcher attempts to learn information regarding the period between trip origin and trip conclusion; the most commonly studied variable in this stage is total trip time. This stage can be complicated by the fact that travel times within urban transportation systems are most typically a function of demand.

Under the most typical circumstances, the work of the four-step model is followed by a cost-benefit analysis. In this process, the researcher, or the administrators of the travel system, attempt to answer questions such as: Do given routes serve the population that they are intended to serve? Are given routes cost-effective? Are metropolitan tax rates justified, considering the net benefit each urban resident derives from the public transportation system?

Critiques

Travel modeling is not without its critics. Existing criticisms typically address the validity of the model itself or the secondary impacts on the infrastructure development itself. Both mathematicians and

transportation researchers have argued that travel modeling must be improved on the mathematical level. These critics have argued that studies of advanced physics or highly advanced supercomputers may improve the accuracy of traffic models.

Critics outside the research community have argued that travel models do not take the secondary impacts of infrastructure projects into account. These critics point out that infrastructure projects shape the environmental and social terrain in ways that could be harmful to natural systems in the affected area or the people and neighborhoods in that same area. Most of these critics are not inflexible in their stances; they are simply calling for social and environmental considerations to be taken into account by both travel models and their associated projects.

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See Also: Activity-Based Models; Microsimulation Models; Mode Choice Models; Networks Modeling; Route Assignment Models; Trip Distribution Models; Trip Generation Rates and Models; Urban Transportation Planning Process.

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Travel Patterns by Income

Income effects are pervasive in transportation. When travel behavior is broken into its individual subcomponents, such as trip generation, trip distribution, mode choice, and path or route choice, travelers of different income groups behave differently.

To consider the situation systematically, high-income individuals or high-income households have greater resources. For the remainder of this article, high-income households will be considered interchangeable with high-income individuals, although it may be true that not all household members in high-income households have equal access to these resources.

High-income individuals are generally assumed to have higher values of time, and this is a frequent assumption built into transportation demand models. This does not mean that their time is actually worth more than low-income individuals', but they are able to outbid others in various pricing schemes. High-income individuals may also act as if they do value their time more, choosing higher-priced transportation options (such as high occupancy toll lanes) at a higher rate than lower income individuals, provided these options do results in time savings.

Income Impacts on Trip Generation

One consistent finding is that higher-income individuals generate more travel, starting with the perhaps obvious finding that adults in high-income households make work tours at a higher rate than low- or medium-income households. Indeed, some, if not most, high-income households are high-income specifically because two or more adults in the household are workers.

Other activities are also generated at a high rate, though in some cases this means high-income individuals do more trip chaining to satisfy all these activities, making maintenance and/or social/recreational stops on a work tour because they may not have as much leisure time to complete these activities as independent home-based tours. A secondary, somewhat indirect impact is that tour generation is positively correlated with household auto ownership, and auto ownership increases with household income.

Income Impacts on Trip Distribution

Long-term decisions, such as residential location and workplace location, are only beginning to be implemented in travel-demand models, though they have been a feature of land use models for a longer period. Higher-income households are better able to bid for more desirable, higher-priced housing.

In many urban regions in North America, this continues to be manifested with higher-income households predominantly located in suburban locations, though frequently in those suburbs with commuter rail service. This pattern is somewhat inverted in European cities, as well as a handful of U.S. cities, where high-income households locate close to the regional core.

Low-income workers generally have the shortest work tours, although low-income individuals living in regions with serious job-housing mismatches can find themselves having to make long commutes.

The white-collar jobs held by higher-income individuals tend to be concentrated in the central business district (CBD), so high-income workers tend to make commute trips to the regional core. In many regions, because high-income individuals are residing in the suburbs, their work commute typically is longer than low- or medium-income workers.

This is, of course, not the case for high-income workers who live close to the CBD. Increasingly in North America, small high-income households (one or two adults) are shrinking their work commutes, while high-income households with children still tend to be located in the suburbs, and these workers have the traditional longer commutes that bring up the average work commutes for high-income workers.

The trip distribution patterns are not as clear for nonwork trips. University trip distance depends on whether universities are centrally located or not, as well as the proportion of students who live on campus versus those who "commute" to school.

Income plays a relatively minor role in trip length distribution, although it may be the case that, in some regions, a higher proportion of low- or medium-income university students live at home (and incur longer trips) rather than live on campus.

School trips are quite short across all income categories (the shortest of all trip categories), though a relatively small number of children travel longer



High-income commuters are less likely to use transit and more likely to commute by automobile and in single-occupant vehicles. For this reason, they are less likely to make use of shared-ride high occupancy vehicles (HOV) and HOV lanes such as the lanes seen here with the least vehicles, center, on Interstate 95 in Virginia. However, high-income drivers are the most willing to pay tolls if it saves them time, suggesting growth potential for high-occupancy toll (HOT) lanes that allow a solo driver to pay a toll in order to join HOV lanes.

distances to go to private schools. This behavior will generally be restricted to medium- and high-income households.

For shopping, personal business, and social/recreation tours, there generally is no direct connection between income and trip distance. There is, however, an income impact if one considers (and models) mode and trip location as a conjoint decision, since transit trips tend to be shorter than auto trips and walk trips are shortest of all. As detailed in the next section, income plays a significant role in mode choice (and combined mode/destination choice decisions).

Income Impacts on Mode Choice

Controlling for household size and workers in the household, high-income households own the most autos. In turn, owning one or more autos in the household greatly increases the likelihood of driving for all travel purposes, not simply for work commutes. As a related point, the individuals (aged 18 and up) in high-income households typically have a car for their personal use, assuming that they have a driver's license. Thus, the amount of shared-ride, high occupancy vehicle (HOV)

mode observed among high-income individuals is much lower than for low- and medium-income individuals.

In the somewhat extreme case (in the United States, at least) of no car ownership, mode choice is dominated by transit and walking/cycling. Low-income households without autos are often classified as "transit captive," though they may not, in fact, make all their trips by transit.

High-income individuals take transit less than low- or medium-income individuals, though this relative gap is lower for commute trips, especially when a rail mode is a valid option. In many regions, the aversion to transit (among high-income travelers) is highest for local bus and lowest for rail modes; commuter rail in particular serves (and is taken by) high-income workers. Taking that into account, rail is still considered less desirable than driving by high-income travelers.

Low-income individuals have the highest propensity to take transit. This may not necessarily translate into low-income individuals comprising the majority of transit riders, though it clearly does in regions where transit is viewed as unreliable and car ownership is widespread.

Propensity to walk, except for school trips, is closely aligned with household income as well. Low-income travelers tend to walk more and high-income individuals walk less. This pattern does not appear to hold true for cycling trips, however.

Income Impacts on Route Choice

Income only enters mode-choice considerations when there are clear trade-offs between saving travel time and paying higher tolls (or fares), and high-income drivers are the most willing to pay tolls if it saves them time. Not all regions in North America, or indeed Europe, offer these trade-offs and in these regions, income should not play a role in mode choice beyond the initial impact on trip origin and destination. However, an increasing number of metropolitan regions are investigating road-pricing options or more elaborate toll schemes. For instance, high occupancy toll (HOT) lanes are designed to allow a solo driver to pay a toll in order to join HOV lanes, which typically do offer a time savings relative to general-purpose lanes.

As road charges increase, all drivers will seek to divert to lower-priced alternatives, but the diversion will be greater among low- and medium-income drivers. If parking charges are increased, this will have different impacts on drivers, with the high-income drivers the least impacted. Low- and medium-income drivers may ultimately shift to carpooling to split costs or even shift to transit, or they may also adapt by parking farther from their final destination and walking. (Not all travel models can capture this particular adaptive strategy, however.) This pattern also generally holds true for congestion pricing, where high-income individuals will divert the least. However, there is some evidence that low-income individuals may have less flexibility in their work hours than high-income white-collar workers and may divert less than economic theory would suggest.

The more widespread the road charges or toll facilities, the more that regional mode choice will be affected, tilting away from single-occupancy driving and toward other modes. Again, one would expect this to impact high-income drivers the least. Whether this can be considered equitable depends on many factors, including what alternatives are available for low- and medium-income travelers and whether the funds raised through tolling or road pricing are used to support meaningful transit options.

Impact of Better Understanding of Patterns

Planning efforts, particularly those that involve changing the relative price of taking transit versus driving (through tolls, road pricing, higher parking charges, or higher fares) will have different impacts based on income effects. Simply ignoring these differential impacts can lead to serious errors in predicting the overall outcome and even effectiveness of these programs.

While income effects are pervasive in all aspects of transportation decision making, representing these income impacts in mode choice is critical, although reflecting household income and auto ownership is superior in terms of explanatory power if this can be achieved. Even transportation planners who do not or are not able to consider income in their transportation planning efforts may hold onto the concept of the captive transit market versus the choice captive market in order to avoid models that are too sensitive or not sufficiently sensitive to changes in transit service and fares.

Beyond the general desire to better understand impacts of plans on travel patterns, there has been increased interest on the part of the U.S. federal government to ensure that regional transportation plans do not adversely impact minority and low-income populations. These requirements certainly suggest, if not necessarily mandate, the adoption of transportation models that can distinguish low-income from medium- and high-income travelers in order to track the various impacts of plans on different income groups. As many regions have begun to consider how to increase revenues to pay for transportation projects, planners in these regions will be making investigations into raising tolls or implementing road pricing, and at the same time they will be asked to consider affordability of travel, particularly for low-income individuals.

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See Also: Automobile Operating Costs; Social Equity and Discrimination in Transportation; Transportation and the Disadvantaged.

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Travel Patterns by Race/Ethnicity

Transportation and transportation policy are often presented in a general sense, in relation to how they affect the population as a whole. However, there exist clear distinctions in the way that various subpopulations use transportation, distinctions that illustrate many of the potential inequalities still present within society. Notable among these are differences in transportation usage by race, ethnicity, and immigration status.

Several aspects of this topic could be explored, including issues of environmental justice and transportation, but this article concentrates on differential levels of access to transportation, usage of different transportation modes, and disparities in commuting times in the United States, in particular.

Key Aspects of Transportation Behavior

To begin, there is the level of access to different transportation modes, referring to the manner by which people get from one place to another. In the United States, the car is king, and most people drive by themselves in order to get to work and also to run errands. Because street networks are ubiquitous, an automobile provides an individual with the freedom to go just about anywhere.

Yet, there are wide differences in travel by racial groups, based on their access to automobiles due to relative disparities in income, driver licensing rates, and other factors such as residential location and transit availability.

Fully 21 percent of black-led households have no vehicle, according to the 2005 American Community Survey. This compares with just 6 percent of white

non-Hispanic households without vehicle access. Hispanic white and Asian-led households fall somewhere in the middle, with 12 percent and 11 percent of households without vehicles, respectively.

Geographic location might help explain some of these variations, but earlier data from 2000 demonstrates that even when location is held constant, African American households are still two and one-half to four times more likely to be without a household vehicle than are white-led households, with Hispanics and Asians in the middle.

Certainly, the availability of mass transit options, such as rail and buses, depends greatly on geographic location. Routes and stations must be developed such that an individual has a reasonable opportunity to get from his or her home to a destination in a timely manner. The availability of transit is quite uneven and remains focused on urban areas with a commitment to transit.

Nonmotorized transportation options such as walking and bicycling are generally available at a low cost to all individuals, but there is a question of distance and safety. Are places reasonably close together and are there available facilities such as sidewalks, bike paths, or easily navigated crosswalks? In this regard, African Americans are more likely to live in densely populated places with greater transit options. Many Asian populations, on the other hand, tend to live more in suburban areas.

Related to the levels of automobile and transit access is the question of modal choice for commuting to work. Modal choice refers simply to which transportation mode—such as carpooling, driving alone, transit, bicycling, or walking—one uses most frequently.

Overall, only 5 percent of Americans utilize transit and another 10 percent choose to carpool. But clear distinctions among racial groups persist, with both African Americans and Asians nearly four times more likely than whites to take transit, according to the 2011 American Community Survey. Hispanics are more likely transit-oriented, but are notable users of carpools, as well. In fact, Hispanics are twice as likely to share a car as non-Hispanic whites.

Immigrants show relatively high levels of both transit ridership and carpool use, and their choice of which mode to use is highly conditioned on time spent in the United States. Each year of residence leads to greater reliance on automobile commuting and less use of transit.

Other mode choices are also affected. According to data from 2007, about one out of four very recent immigrants with four years or less in the United States carpools. Unlike transit, carpooling is available to everyone with access to a car, regardless of where they work or live. Given their lack of access to automobiles, carpooling may be necessary for recent immigrants who do not live and work near routes served by public transit.

While many (but by no means all) immigrants settle initially in inner-city locations, the majority of workplaces are located within the suburbs. Private shared-ride opportunities, including shuttle buses and vanpools, sometimes provide transportation from residences to suburban worksites. With more years in the country, carpool use by immigrants drops off but remains high for several years until finally approaching the levels of U.S.-born residents after 21 years. The choice of walking or biking starts off high among very recent immigrants but falls off rapidly. The initial location of immigrants in so-called ethnic enclaves that include homes, workplaces, and shopping may make walking more convenient. As immigrants establish themselves, they might leave these enclaves for more distant neighborhoods and so increase their reliance on automobiles.

Travel Time

Finally, there is a question of travel time, or how long it takes somebody to get to work. Data from 1980 showed that African Americans had significantly longer commutes than whites, with Hispanics in the middle. Of course, travel times are heavily conditioned on mode of travel, because minority groups are more likely to take transit and because transit takes more time than automotive travel.

But considering just those who travel by automobile, there have been documented differences in commute time by race. Studies using 1990 data demonstrated that, among automobile users, white males had a longer commute, but this was compensated for by higher incomes. African American women, on the other hand, were more likely to suffer long commutes, generally from their inner-city residences to a suburban workplace, but without compensating wages.

The most recent data show continued racial and ethnic differences in travel time. The 2009 American Community Survey indicates that non-Hispanic whites enjoy shorter commute times if they

are driving alone by car. African Americans spend more time in taking public transportation. Some of these differences can be attributed to the location of each group within metropolitan areas and the relative locations of work.

Many of the disparities are likely also related to differences between metropolitan areas. The metropolitan areas with the longest commutes, including New York; Chicago; Washington, D.C.; and Atlanta also happen to have the highest populations of African Americans. This could skew the national figures.

Socioeconomic Status

In all of this discussion, it is important to remember that race, ethnicity, and immigration status are bound up with income levels; minorities and recent immigrants are usually poorer than white natives. In addition, different racial and immigrant populations in the United States tend to be found in larger metropolitan areas, and, within these, concentrated within the more densely populated neighborhoods.

As a result, the distinctions observed in transportation usage are partially correlated with levels of socioeconomic status and geographical location. At the same time, transportation usage still varies even when such factors are controlled for. This demonstrates, once again, that race and ethnicity continue to be a powerful driver of difference within American society.

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See Also: Reverse Commuting; Social Equity and Discrimination in Transportation; Spatial Equity Analysis; Transportation and the Disadvantaged; Travel by Mode; Travel by Persons; Travel Choice; Travel Patterns by Income; Travel Patterns of the Elderly; Travel Patterns of Women.

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Travel Patterns of the Elderly

Most industrial societies are aging rapidly; people are living longer but having fewer children. Most people in the industrial world will soon pass their 65th birthday as drivers, and if not drivers, then car passengers. Yet, on average, people lose some of the skills necessary to keep driving safely as they age; many others, particularly women, do not wish to keep driving even though they are objectively competent to do so. The increasing automobility of seniors creates a number of policy challenges.

Most transportation researchers have focused on three substantive areas: the travel patterns of seniors, driving safety, and viable mobility options. Cutting across these areas are differences by gender, race, ethnicity, immigration status, residential location (for example, suburban versus central city), household structure, and income.

Basic Patterns and Changes Over Time

Older travelers take a much higher percentage of their trips in a car, as a driver or passenger, than did comparable-age people in the past. In fact, seniors take a slightly higher share of their trips by car than middle-aged people; older Americans never take less than 75 percent of all trips and 90 percent of shopping trips in a car. Conversely, less than 3 percent of all trips by seniors are made on public transit; seniors are two to three times more likely to walk than to take public transit.

Older travelers today also take more trips than comparable cohorts of seniors did a decade ago. At the same time, older people make fewer total daily trips by any mode than those younger. This difference is often seen as evidence of a mobility loss. Yet all evidence suggests that older people are very mobile until well into their 70s—many have simply

stopped making five weekly work trips, and so their average number of daily trips drops. This is hardly evidence of mobility loss. In fact, older people for at least a decade after they retire make more non-work trips than younger people.

Older people also take longer average nonwork trips than comparable travelers in the past because they have more time to travel, and possibly because they are no longer constrained by the need to conduct these activities near their job or on the way to or from work. Other possible causes for the increase in both the number of nonwork trips and their length may be the convenience offered by the car, living in low-density and rural places where longer trips are necessary, having higher average incomes that are associated with increased trip making, and/or staying in the labor force past traditional retirement age, thus retaining daily work trips that comparable seniors in the past did not make.

Driving Competence and Cessation

Older drivers are among the safest on the road; they obey the law, do not drink and drive, wear their seat belts, and rarely take deliberate risks. Because they take fewer total trips than younger travelers, and often not at peak periods, they have lower per capita crash rates until roughly the age of 80.

However, older people are more likely to die or be seriously injured in a crash of comparable severity than those younger. Moreover, as they age past 75, older drivers on average have more crashes per exposure (that is, miles driven). Many driving skills do decline with age, and most older people will come to a point when they can no longer safely drive.

Older drivers recognize many of their driving deficiencies; they self-regulate, avoiding driving situations they consider dangerous or stressful, such as at night or in heavy traffic or bad weather. However, studies show that not all older drivers accurately recognize their problems; it is not realistic to assume that, as society ages, self-regulation will prevent rising crash rates among older drivers.

There is no reliable and cost-effective way to easily screen older (or younger) drivers for their potential of having serious crashes. There is also a lack of cost-effective methods shown to meaningfully improve the driving of older people; most training or education methods associated with lower crash rates have simply persuaded older people to drive less rather than teaching them to drive better.

Automatically testing drivers who reach age 70 or 75 does not reduce overall crash rates, although it does encourage sometimes capable (often women) drivers to stop driving. Such testing is costly and yields no discernible benefits; New Zealand abandoned this expensive requirement because it had no effect on crash rates. A famous study contrasting two Scandinavian countries, one with rigorous age-based testing (Finland) and one without (Sweden), found that Finland did not have as many licensed older people—but no fewer crashes involving older drivers than Sweden. Seniors in Finland experienced a much higher total fatality rate, though, because when they gave up driving, older people used more dangerous modes such as walking and cycling.

Older people may take in-class driver training, but five decades of studies find little evidence that seniors who attend such classes actually lower their crash rates, although they may lower their rates of getting traffic tickets. This counterintuitive outcome may represent increased driving by those who take such courses because they feel more confident; more driving translates into greater exposure or likelihood of having a crash. Current research focuses on how changes in automobiles themselves (self-braking, for example), as well as changes in the highway system (clearer signs and lane markings, for example), might make driving safer for older people. Given that one out of five drivers on the road will be over 65 within a few decades, it may be important for highway and traffic departments to make the older driver the “designated driver.”

Developing Mobility Alternatives

While seniors are more mobile than comparable people in the past, some seniors do suffer serious and growing mobility problems as they age, as well as declining incomes. The number of seniors who never leave home on one or more days of the week, or who report mobility problems, has grown substantially.

Policy options include expanding mandatory paratransit services for people with disabilities as the population ages, offering more-responsive public transit services (for example, better information particularly enroute, more helpful drivers, being allowed to sit down before the bus starts, routes and schedules targeted to the needs of older people), expanding community-based transportation systems, and supporting volunteer voucher programs (in which eligible older travelers ask someone they

trust to drive them and pay with a voucher subsidized by a public program).

However, older people’s reasons for just staying home may be complicated; the same conditions that can reduce older people’s mobility or impair their driving may reduce their willingness to go out at all. Simply providing transportation may not overcome the physical, emotional, or financial constraints that leave some older people isolated. It is important that transportation options be offered as part of a package of assistance to older people with mobility problems.

Conclusion

Society is aging; the travel needs and patterns of seniors are changing in ways that cannot always be predicted from the largely cross-sectional research already done. The challenge is to identify and implement a variety of approaches that lead to the safe mobility of older travelers now and in the future.

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See Also: Accessibility and Mobility; Elderly and Disabled Travelers; Elderly Driver Safety Issues; Social Equity and Discrimination in Transportation; Transit Demographics; Transportation and the Disadvantaged.

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Travel Patterns of Women

Women’s travel differs, often substantially, from men’s; around the world women tend to have different trip lengths, more complicated trip patterns,

different reasons for travel, and less access to the most advanced transportation methods. These patterns are due in part to ordinary sociodemographic characteristics such as income or employment status but they are also related to sometimes complex social, cultural, and psychological factors. Women tend to be poorer, for example, and income determines many aspects of travel choices.

Yet even when women and men have the same personal or household income, their travel patterns may still differ widely. Moreover, while some gender differences in travel patterns have been slowly disappearing, others have stubbornly remained. Even the movement toward parity among the sexes disguises sometimes remarkable travel differences between otherwise comparable women and men in both developing nations and in the industrial world.

A large body of research shows that gender differences in travel patterns around the world can be linked to four inter-related factors:

1. Disparities in income, education, employment, and household resources
2. Differences in access to, and use, of transportation options
3. Social, cultural, and religious norms about both gender-appropriate activities outside the home and about travel choices
4. Personal security and safety concerns

Developing Nations

Women's travel patterns in general are a response to, and a result of, the state of economic development in their country as it interacts with pervasive cultural and religious norms about women's appropriate behavior and access to transportation resources. In developing nations the differences between women and men's travel patterns are wider than in the industrial world, and greatest in the poorest countries. In contrast to average patterns in the industrial world, women in developing countries often spend longer time traveling due to the nature of their jobs, their need to combine household and child care duties with their commutes, and their use of slower modes.

Being forced to rely on slower, more physically demanding transportation modes continues to keep even employed women poorer than men. Income and residential location are significantly related; poor people are often forced to live at great distance

from urban concentrations, creating lengthy commutes. Moreover, the less income a woman makes, the less she is in a position to bargain for access to better household modes of transport. Since lack of transport reduces women's income potential, their social status remains too low to affect the division of transport resources in their own household.

Women in developing nations use different transport modes than men. In urban areas women are more likely to walk or use public transit and less likely to have a car, since ownership and use of vehicles is often a male prerogative. When they do not walk, women are often limited to informal transportation solutions (for example, donkey carts and ped-taxis) because they are cheaper, even if dangerous and unreliable. Women's travel is also restricted by cultural and religious norms. In some countries there are significant cultural barriers to women adopting new technology or certain modes. Moreover, fear of crime, sexual assault, robbery, or harassment constitute a major mobility problem for women in developing countries. Women are often the targets of sexual harassment while walking or riding public transit, exacerbated by inadequate lighting and small, isolated paths connecting where they live to bus stops. Women in developing countries also have safety concerns; as pedestrians they fear falling on poorly maintained roads or footpaths, or losing their loads, or being hit by motorized vehicles.

Developed Nations

While few women in industrial nations face anything like the deprivation of women in the developing nations, there are strong parallels. There are persistent differences between women and men in travel patterns, only some of which can be explained by economic and demographic factors such as employment status, occupation, income, and life cycle.

As the employment opportunities open to women have increased their income, many important travel differences between women and men in all aspects of travel—mode used, trip purpose, trip length, trip patterns—have clearly decreased. In 2006 more of the licensed drivers on U.S. highways were women than men. In 2011, licensing was close to parity among the sexes in the United States. However, women with licenses drive less (measured in miles/kilometers) than men of comparable age with licenses (and the gap grows wider with advancing age).

One of the most persistent differences between women and men is work trip commuting distance. Almost all research shows that women commute shorter distances than men, even controlling for other sociodemographic variables such as income, in every industrial country where data are available. This may result from persistent gender roles; research shows that married women with the most children have the shortest commutes of all commuters, while men's commutes were not affected by the number and age of their children.

Women in the industrial nations in all life cycles made more shopping trips and more chauffeuring ("serve passenger") trips than comparable men. Salaried married women with children made twice as many serve passenger trips as comparable men. Research from many nations shows that women are more likely to chauffeur their children, and it has also been found that organizing chauffeuring duties was considered the mother's responsibility even if she was not conducting the trip. Women also more often trip-chain, that is, link other trips to their work commutes, to drop off or pick up children at school, day care, or recreational activities, or to conduct household duties such as shopping.

These differences, as in the developing nations, are due in part to disparities in income but are not fully explained by income or employment. Some are clearly due to cultural norms about parenting. Many studies find that salaried mothers continually challenge themselves about their parenting duties whereas fathers in comparable situations do not.

In addition, women in industrial nations have different personal security and safety concerns than men. While women at all ages are significantly less likely to have car crashes than men, and are more likely to be law-abiding drivers (not drinking and driving and always wearing their seat belts), they are much more likely to be significantly injured or killed than men in crashes of comparable severity.

Moreover, they also fear falling on sidewalks or being hit by cyclists or people running on footpaths. And even women in developed countries have personal security fears; they report harassment and even sexual attacks in public places and while using public transport modes.

Conclusion

Women, regardless of the level of economic development in their community or nation, have less access to better or faster transportation resources, display different and more complicated travel patterns, and are more influenced by fear of attack or harassment than are comparable men.

These gender differences are a complex response to differential economic resources, societal norms about the use of transport modes as well as household and child care constraints—themselves embedded in a web of cultural attitudes and societal norms. Gender differences are starkest in the developing world because women's opportunities for paid employment are less and their social status so much lower than comparable men's. But the parallels are many and strong.

Researchers suggest that we can address these issues by requiring public projects to conduct gender-specific analyses of the costs and benefits of public expenditures, encouraging more women to enter the transportation planning and research fields, and ensuring the inclusion of gender indicators in transport project design as several European nations have done.

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See Also: Transit Demographics; Transit Safety; Transportation and the Disadvantaged; Travel by Households; Travel Patterns by Income; Travel Patterns of the Elderly; Women's Issues/Gender Issues.

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Travel Pricing

Travel pricing is a concept that covers a wide range of policy measures, which involve payment for road access in direct relation to usage criteria rather than paying a fixed network access fee unrelated to the actual use, or paying proxy charges, such as road fuel taxes. More specifically, travel pricing is a term that could be used as a generic synopsis of the cases where a monetary fee is a prerequisite to access part of the road network as a way to regulate traffic congestion growth and its unwelcome consequences.

This pay-to-use road space could vary from a high-speed motorway (or even from a motorway's single lane) up to a city center-wide area of a megacity such as London or Singapore. In terms of operational complexity, travel pricing could be as simplistic as a one-point entry road charging zone that is tollbooth oriented or as multifaceted as a fully automated electronic road pricing system for a whole city or a double cordon system that has been integrated into a much broader local

authority's strategic agenda for improved sustainable mobility.

The Need for Travel Pricing

Travel pricing is a restraining mechanism that has been applied to satisfy the twin objectives of reducing severe road traffic congestion and preventing environmental degradation in urban environments. These remedies could range from straightforward themes, such as air and noise pollution, to more complicated ones, such as the degradation of aesthetically displeasing landscapes.

Travel pricing is also a way to promote healthier and more socially sustainable ways of commuting, such as bicycling and walking; to encourage modal shift to public transport modes; and to provide an incentive for reducing excessive fuel consumption.

Perhaps of equal or greater importance in some situations is another fundamental, but sometimes underlying, motive behind the implementation of travel pricing, and that refers directly to the city economy or, in some particular pricing cases, of wider context to help support a nationwide economy. Travel pricing is gradually becoming an invaluable revenue generator that has the advantage of being clearly and immediately associated with transportation operations by road users. Travel pricing's function as a resource collector could provide the funding basis for transport improvement packages for the cities choosing to introduce and run this as part of their travel demand plans.

The value that travel pricing has is usually the critical criterion for its eventual acceptance in both political and societal terms, and thus the cornerstone for its successful introduction by authorities around the world. This is because travel pricing in all its variations provides institutions with an effective and direct way to deal with the costs associated with operating, maintaining, and expanding a transportation system to meet growing travel demand. Furthermore, it is sometimes the only vital fund-raising apparatus available to policy makers and stakeholders that has the potential to help them overcome the inefficiencies of the centrally governed transportation subsidy operations.

However, any charging program that generally has the intention of reducing the number of private-vehicle trips may be put in an awkward position if it is seen to be raising funds to pay for more facilities for private motor vehicles.



In Los Angeles, the high-occupancy toll (HOT) lane system uses “switchable” transponders for the occupants of the vehicle to indicate the number of people in the vehicle by setting a switch. The toll collection system automatically determines whether a toll should be charged based on the setting.

Types of Travel Pricing

Travel pricing is not a single policy or a technical measure with a one-dimensional character but rather a collection of various road movement charging strategies. Namely, these could be congestion pricing (peak hour/nonpeak hour), variably priced traffic lanes, express tollways, area-based or cordon-based road pricing, variable tolls, electronic road pricing, toll roads and toll motorways (tollbooth-operated or automated), and mileage-based charging.

There are four broad categories into which the travel pricing strategies could be organized:

1. Variable tolls on entire roadways
2. Variably priced lanes that are founded on having variable tolls on separated lanes within a highway, such as high occupancy toll (HOT) lanes or express toll lanes
3. Zone pricing that is either a variable or fixed charge drivers need to pay while traveling within or into a designated city area (usually known simply as congestion charging or pricing)
4. Mileage-based charges on all roads within an area (area-wide charges), which may vary by the level of traffic congestion and requires advanced technology to be applied

The two basic criteria that allow these different strategies to fall under the same broad policy classification are (1) the financial fee to access road space that is being imposed on the drivers, and (2) the fact that these measures serve in a significant degree the goals of relieving traffic congestion, mitigating environmental impacts of travel, and funding transport operations that otherwise could not have been realized.

Societal Implications for Travel Pricing

Despite its potential to benefit societal well-being in terms of mobility, sustainability, and transport investments, travel pricing in all of its forms suffers from low public acceptability. Especially if no regulatory traffic policy was used to manage road space before its implementation and thus was free, the measure will have strong public opposition to overcome.

Many people, especially immediately before the introduction of the measure or before a referendum that is to decide the future of such a pricing mechanism, tend to dismiss its pro-social value in terms of reducing traffic congestion and improving environmental conditions and focus solely on its “penalizing” and “socially exclusive” character. The restrictions of access implied by the toll requirement are seen as being against the notions of freedom and choice. Travel pricing can be easily labeled by many people, and more likely by those who have not experienced the measure before, as an additional form of prejudiced taxation designed to make them carry one more financial burden.

Nonetheless, various research studies have proven that as car users become more accustomed to road pricing measures, they are far more likely to support them because of the travel savings they experience because of the reduced traffic congestion.

Moreover, other transport users see the potential of travel pricing to support their preferred modes of transportation by providing, first, a more livable urban environment that can adopt in a more effective way more sustainable forms of traveling, and, second, a funding instrument that could finance infrastructure and services dedicated to alternative transportation.

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See Also: Automated Road-Pricing and Toll-Collection Systems; Cordon Travel; High Occupancy Toll Lanes; Road Pricing Schemes, U.S. and International; Traffic Demand Management.

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Travel Speed Models

Motor vehicles are major contributors to air pollution, and, as a result, there is increasing interest in finding accurate ways to model vehicle emissions. Accurate information about emissions is necessary for many purposes, including transportation planning, to measure the effects of policies, and to estimate environmental impact.

One approach to the problem of estimating emissions has been the development of travel speed models, which are based on the understanding that speed of travel is one key factor in the quantity of emissions produced by a vehicle. Among travel speed models, the average speed model, based on the average speed of a vehicle over an entire trip, is commonly used. However, the average speed model also has drawbacks, and researchers have developed more sophisticated variations on the average speed model in order to ameliorate its perceived shortcomings; in addition, a more complex model based on instantaneous speed is also available.

Emissions Modeling

Motor vehicle exhaust includes many harmful air pollutants, including carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO₂), volatile

organic compounds (VOCs), and particulate matter (PM). Estimation of the amount of these compounds produced by vehicular travel in an area is an important aspect of transportation planning and environmental impact assessment, and a variety of models have been developed to aid in this process.

In broad categories, the available models include aggregated emission factor models, which look at only broad categories of driving (for example, urban, rural) and broad categories of vehicles. Average speed models are more sophisticated and incorporate information about the average speed of a vehicle over a given trip. Traffic situation models are even more complex, including information about traffic situations (for example, free flow, congested), as well as average speeds. The most sophisticated models are instantaneous models, which combine information about instantaneous speed and acceleration to calculate the rate of emissions.

Despite the fact that more sophisticated models are available, average speed models are still popular in emissions estimation. Three reasons for their continued popularity are that average speed models are relatively simple and easy to understand, the data required to use them is commonly available, and software to compute them is readily available and often free.

However, average speed over the length of a trip is a relatively crude measure; for instance, the same average speed could be achieved by driving at a consistent pace, or by periods of fast and slow driving with frequent stops, and the fuel consumption and emissions patterns for these two modes of driving would be expected to be very different. This drawback is more obvious with lower speeds and urban driving, as opposed to high-speed, highway driving.

Examples of software to compute emissions using average speed models include MEET (Methodologies for Estimating air pollutant Emissions from Transport), developed in Europe to estimate energy consumption and emissions of various pollutants with different modes of transportation, including road, rail, water, and air; and COPERT, a widely used model now in its fourth version (COPERT IV), which was developed to calculate emissions and fuel consumption by different types of vehicles and which estimates emissions of both regulated and unregulated pollutants.

Instantaneous models were developed to provide a more detailed description of emissions by

gathering data in short intervals, typically one second in length, and relating emissions rates to vehicle operation during those intervals. They are particularly useful for microscale models, such as modeling air quality on a particular stretch of road, while average speed models are more useful for macro-scale models. The chief disadvantages of instantaneous models are the amount of detailed data required to use them, the expense involved in collecting such data, and the difficulty of measuring emissions accurately on so small a scale. If the information supplied to an instantaneous model is not accurate, this may eliminate any potential benefits of using the more complex model.

The Traffic Energy and Emissions (TEE) model was developed to address some of the deficiencies of the average speed model. It may be considered a “corrected average speed model” because it is still based on the average speed of a vehicle but also considers the effects of road congestion on emissions. The TEE model includes a corrections factor using information about traffic signals, link length, and traffic density, as well as average speed, to estimate the amount of time spent in different phases of driving, including acceleration, deceleration, idling, and cruising.

Results

Looking at “hot” exhaust emissions (that is, emissions after an engine has reached operating temperature), researchers found a U-shaped relationship between average speed and emissions. Looking specifically at NO_x emissions, they found that emissions were highest in the range of 6 to 12 miles per hour (10 to 20 kilometers per hour [km/h]) and over 74 miles per hour (120 km/h) and lowest in the range of 37 to 50 miles per hour (60 to 80 km/h).

Several studies have compared estimated emissions as calculated by various models with actual emissions measured by various sensing methods. In a series of tests in Sweden, the COPERT III model produced estimations close to those measured for CO and NO_x , but had poorer agreement for CO and hydrocarbon (HC) emissions. Measurements of emissions conducted in the United Kingdom, gathered by driving vehicles continuously through tunnels and collecting measurements from several points along the way, produced results showing that several models, including COPERT III,

predicted higher emissions than were actually measured during vehicle operation in the tunnels. This was particularly true for predicted NO_x , and greater variation between the predicted and measured NO_x emissions was found for heavy-duty vehicles than for automobiles.

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See Also: Emissions Modeling; Carbon Dioxide Emissions; Carbon Monoxide Emissions; Traffic Congestion; Vehicle Emissions Standards.

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Travel Surveys

At any given moment, travel is taking place across the United States. A snapshot of travel will show people traveling for different reasons, by different travel modes, and between different origin/destination (O-D) pairs. The purpose of travel surveys is to capture information about the various types of travel and supplement it with demographic details about the travelers in order to recreate this snapshot.

The objective is to replicate these patterns in travel demand models and to forecast travel patterns for long-range transportation planning efforts. Several types of travel surveys are conducted across the United States. Regardless of the type, at the core, the surveys capture key elements of travel: origins and destinations, time of day, trip purposes, and travel modes. Types of travel surveys include the following:

- Household travel surveys
- Commercial vehicle surveys
- Workplace surveys
- Special generator surveys
- External travel surveys (also known as cordon line surveys)
- Transit on-board surveys
- Visitor surveys
- Special surveys of subsets of travelers, such as long-distance personal travel surveys, freight surveys, and surveys of bicyclists

The history of travel surveys began with the 1944 Federal-Aid Highway Act, which authorized funding for urban highway extensions. Around this same time, the Bureau of Public Roads issued the *Manual of Procedures for Home Interview Traffic Studies*. The first travel surveys were conducted in Tulsa, Oklahoma; Little Rock, Arkansas; New Orleans, Louisiana; Kansas City, Missouri; Memphis, Tennessee; Savannah, Georgia; and Lincoln, Nebraska.

Over time, the methods used to conduct these surveys have evolved as a result of technological advances, societal trends, and travel demand modeling needs. Travel survey methods are currently evolving to reflect advanced technology that can obtain the travel behavior details with a reduced respondent burden.

The most frequently conducted travel surveys are household surveys, commercial vehicle surveys,

external station surveys, transit on-board surveys, and workplace surveys (in that order). An overview for each of these is presented below.

Household Travel Surveys

The travel behavior details captured in household travel surveys can inform the following questions:

- Why do people travel outside the region?
- Where do the people who work in the central city live? Are they centralized enough for express bus service?
- Where are the best park-and-ride locations?
- Who trip chains? Where do they stop? What type of mixed-used developments would help reduce vehicle miles traveled (VMT)?
- Where are the best locations for electric vehicle recharging stations?

The general approach entails a random recruitment of region households, documenting household member demographics, and asking all (or a portion of) household members to record all trips made for a 24-hour or 48-hour period. The typical sample size is between 1 and 2 percent of the universe of households in a region. Current technology includes computer-aided telephone interviewing (CATI), Internet-based computer-aided self-administered (CASI), postal mail, and passive collection through global positioning data obtained from provided units or via a respondent's smartphone.

In addition to this base collection of data, recent travel surveys have included supplements that focus on a specific population subgroup or mode-usage group, such as university student surveys and long-distance travel surveys.

Commercial Vehicle Surveys

This type of survey documents the origins and destinations of travel by vehicles owned by businesses rather than by households. Typical data looks at route usage, intra- versus inter-regional travel, trip length frequencies, and cargo/transport types. Of particular interest is how these movements vary by truck type.

As with household surveys, businesses are recruited and a subset of their fleets sampled. Drivers of the sampled vehicles are asked to keep a log of

all stops made (including for personal reasons) for a 24-hour period. GPS data is sometimes substituted for the paper log.

External Travel Surveys

External travel surveys are also referred to as “cordon line surveys.” These surveys are designed to document travel into and out of a region. Historically, these surveys were conducted at specific points on the roadway network that led into or out of the region (hence the name “cordon line”). Cars were stopped, interviews conducted, and data collected. As traffic volumes and safety concerns grew, the methods evolved to the current use of video license plate capture and transcription; emerging technologies include Bluetooth readers.

Transit On-Board Surveys

Transit on-board surveys document the use of the transit system by riders. They are designed primarily to document origins and destinations of travel, transfers, and a small amount of demographics. Bus trips from across the system are randomly sampled.

The “universe” is documented through counts of how many people board and alight from each vehicle across all routes during a given time period. Traditionally, these surveys were conducted using pen and paper; surveyors distributed the surveys as passengers boarded and collected them as passengers alighted. Now, handheld tablets and other devices are used to conduct the surveys. Sometimes the full survey and sometimes basic information is collected and the remainder is conducted via Web or telephone.

Workplace Surveys

Similar to external travel surveys, workplace surveys intercept people as they arrive at randomly sampled employer locations throughout a region. The respondents are categorized as employees or visitors to the site, and questions are asked regarding origin and destination of travel, home location, trip purpose, and so forth. These surveys are commonly conducted using tablet computers for immediate entry of responses, with real-time geocoding of the origin and destination data.

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See Also: National Household Travel Survey; Transportation Surveys; Travel by Households; Travel by Persons; Travel Demand Forecasting.

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Trip Chaining

A trip chain is a sequence of trips taken to pursue different activities. A simple trip chain might take the form of home–activity–home, namely, a trip chain with only one stop and two trip legs. Different taxonomies of multi-stop trip chains are possible, depending on the trip purpose and mode of travel. For example, a sequence of trips might be considered a shopping-trip chain or work-trip chain because work and shopping activities are both included. These trips may be taken by car only or a series of modes (e.g., walk, carpool, transit, etc.); the latter case may also be considered a mode-chaining travel behavior because it involves more than one mode.

In trip chaining, trips may be taken by the same person or different persons in the same or different households. In addition, socioeconomic and demographic characteristics (for example, age, gender, income, auto availability, multiple-worker households, and presence of children in the household) as well as transportation system changes may play a role in the realization of different trip-chaining patterns.

A one-worker household might reach five destinations within the same trip chain with six trips. A second household might reach only three destinations in six trips. It appears that bundling more trips

in a single chain results in a more efficient behavior. Some of the unintended consequences of longer trip chains may include longer commutes and longer morning and evening peak travel periods.

Trip-chaining behavior has important implications for travel forecasting. Traditionally, in urban travel forecasting, different trip purposes are estimated separately for home-based and non-home-based activities before combined and assigned to transportation networks.

The underlying assumption is that each trip from one location to a second location is independent of a subsequent trip from the second location to a third location. In that assumption, when trip-chaining behavior increases—given a constant total number of trips—the number of estimated home-based trips would be underpredicted while the number of estimated non-home-based trips would be overpredicted. It is important, therefore, to understand and account for trip interdependencies in trip-chain formation to improve the sensitivity of travel demand forecasting models. Considerable effort has been devoted to the study of trip-chaining behavior and has resulted in conceptual and methodological advancements.

Descriptive Analysis, Exploratory Studies, and Econometric Models

Standard descriptive tools such as tables of frequencies, histograms, and diagrams, as well as classification and regression, have been widely used with travel diaries and have provided empirical evidence of trip-chaining behavior. Other econometric models used include hazard models in order to account for the continuous nature of the decision-making process underlying activity performance. These techniques have uncovered interdependencies among socioeconomic, demographic, spatial, and other factors (for example, sequence, duration, nature, and location of stops) that affect trip-chaining behavior.

Such approaches have shown evidence of a higher propensity of trip-chaining behavior among multiple-worker households, and that these individuals had a higher propensity to make simple work trip chains when work trips are scheduled in the peak period. Female travelers have been shown to have a higher propensity to trip chaining in the midday in suburb-to-suburb trips, contrary to male drivers on the way from the suburbs to the city.

Suburbanites with lower accessibility to destinations were found more likely to exhibit trip-chaining behavior. Furthermore, factors such as life cycle stage, marital status, gender, employment status, education, income, the presence of children, and residential density were important determinants of trip-chaining behavior.

Activity-Based Models

The activity-based approach to travel demand analysis envisions travel as a derived activity that links, spatially and temporally, other activities in which people engage. A variety of themes have been explored in trip chaining: scheduling time and space of activities by individuals, the interdependencies between one individual and another in the same household, interdependencies between the activities in which one participates, patterns for various days of the week, and so on.

If, for example, a traveler uses the public transit system to get to work in the morning, then the same traveler excludes the possibility of doing, on the way home from work, certain things that might require a car. In addition, if another traveler cannot participate in some activity on a particular weekday, that person might need to reschedule that activity to a different day of the week or, possibly, some other member of the household might be able to undertake various tasks.

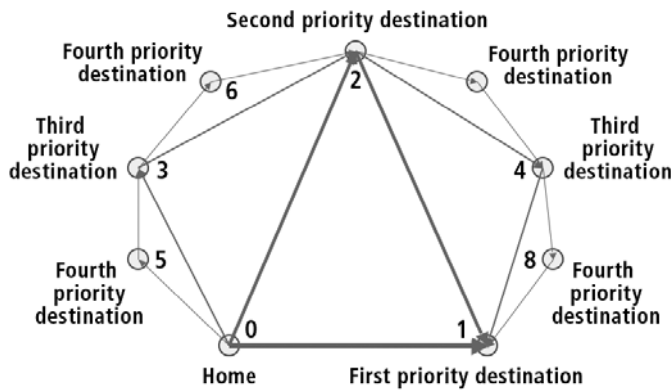
With respect to the methodology used, the main concern in the activity-based analysis is to arrange a given set of activities undertaken by an individual or household. This arrangement, if seen as a problem of activity scheduling, resembles the traveling salesman problem that has received much attention in the operations research literature. A number of mathematical programming, combinatorial, and heuristic methods are available. In addition, activity chaining has been seen as a subproblem of the individual activity program-generation problem.

Distinct activity patterns are usually generated by cluster or factor analyses of household socioeconomic and travel data, and are subsequently related to travel frequency and purpose, household composition and lifecycle status, and household economic factors.

Entropy-Maximizing and Gravity Models

The entropy-maximizing approach is deterministic in nature and treats spatial interactions in general,

Figure 1 Decision process for intermediate trips



Source: Paul Metaxatos.

and trip chains in particular, as continuous flows. The approach results in an equivalent optimization problem that gives the gravity model as a solution. On the other hand, the gravity model is probabilistic in nature and treats spatial interactions as discrete events. Both approaches can be included in the traditional urban travel forecasting procedure.

The underlying trip-chaining decision process is illustrated in Figure 1. In this example, a trip chain starts with a high-priority trip, such as the trip to work (0, 1). On the way, if a traveler needs to stop at the dry cleaners, a suitable destination would be chosen conveniently for the trip from 1 to 2. Therefore the trip from 0 to 1 is now via 2 (that is, there are now two trips, one from 0 to 2 and one from 2 to 1). Similarly, either leg 0 to 2 or leg 2 to 1 could be interrupted by another intermediate destination resulting in trip chains 0, 3, 2, 1 or 0, 2, 4, 1, respectively, and so forth.

This approach is similar to the order in which one might fill out an appointment book; work trips are filled out first, medical or other business appointments next, stopping for gas or a convenience store last. Therefore, the choice of destinations is made in a certain order over time, but this order need have little to do with the order of the destinations in the trip chain. Destinations, rather, are prioritized by the order in which the decision was taken or by the importance of the decision.

Thus, modeling can proceed in steps. The choice of the highest-priority destination would be modeled first. At the next step, the choice of an intermediate destination would be modeled. At the next

step, an intermediate destination on one of the previously determined trips would be considered. Therefore, for modeling purposes, it is enough to consider how a single intermediate destination or stop is chosen.

The behavioral implication of this approach is that the terms *mandatory activity* and *discretionary activity* are viewed as relative terms with respect to the underlying decision process. A doctor's appointment, for example, is a discretionary activity with respect to going to work, but mandatory (or less discretionary) in comparison to a visit to a fast food restaurant.

The process above can be operationalized using the probabilistic threshold-choice theory. Within this theory, an individual balances the utility derived from a stop at an intermediate destination against the increase in travel cost incurred, but is otherwise indifferent to variations in travel costs (for example, distance, time, effort, etc.) if and only if anticipated travel costs do not exceed the individual's current threshold level. The choices are then undertaken stage by stage only for the allowable threshold level, and there is a genuine possibility that any given trip considered by the individual may not be taken. The threshold-choice theory assumes only partial information about individual behavior. If, for example, all that is needed is a six-pack of soda, then it is not assumed that a commuter knows the optimal location to buy it. Thus, from a behavioral point of view, the researcher pursues a satisficing rather than a maximizing theory of individual behavior. Moreover, the theory does not assume any explicit search process involved in the choices of destinations.

Under some general independence conditions, it can be shown that larger costs incurred during a deviation for an intermediate activity will reduce the probability that the traveler's threshold levels will exceed these values and reduce the probability of a realized stop. In other words, threshold behavior reduces the mean frequency of potential intermediate stops to a smaller mean frequency of realized stops at intermediate destinations. Moreover, it can be proven that the mean realized single-stop trip-chain frequencies are representable by monotone and, in particular, exponential gravity models.

Markov Processes

Stochastic processes, and in particular Markov processes, have been used to model the sequence

of decisions involved in trip-chaining behavior. Markov models have been developed either as stand-alone models or as models that operationalize activity-based arguments in simulation efforts. The essence of the approach is to estimate the transition probability matrix that indicates functional connections or sequences between activities, as well as strengths of linkages between origins and destinations. Usually, trips from and to home and different activities, and between activities, are structured as an absorbing Markov chain in which one state, the return-home trip, is absorbing and all other states nonabsorbing.

Discrete-Choice Models

The disaggregate utility maximization framework has also been applied to multi-stop, multipurpose travel behavior. In this framework, discrete-choice models are used to develop a sequential model where successive destinations are chosen independently of one another while capturing the effects of past and future travel choices on present travel decisions.

The basic theoretical argument governing the formation of trip chains within this framework is the consideration of the decision for nonwork travel behavior as a choice from among a set of feasible daily paths. Time and income constraints limit both the coordination of trips and the choices of destinations. A condition can then be derived that equates the marginal rate of substitution between linked and unlinked trips with the ratio of their generalized time and travel costs. An increase in income, for example, would thus result in higher opportunity costs and a greater propensity to form trip chains.

Simulation Methods

Increasingly, researchers are attempting to operationalize the activity-based approach, mainly using simulation models to handle the behavioral dimensions of information acquisition, information representation, information processing, and decision making. Simulation methods can relax the intractability of analytical models when there is need to incorporate more complex theoretical notions.

It has been argued that regulating trip-sequencing, route, and destination choice by distance or other attribute considerations either in a sequential or a simultaneous decision-making framework will

remain ultimately an ad hoc heuristic, which is very difficult to represent in a detailed analytical model.

The counterargument is that simulation models offer an attractive alternative because observed relative frequency distributions can be used to categorize sample respondents into behavior types. Such a framework would then allow the utility of alternatives to change depending on past stops or future stops for planned trips.

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See Also: Freight Transport Models; Gravity Models; Origin–Destination Models; Residential Location Models; Transportation Planning; Travel Demand Forecasting; Travel Modeling; Trip Distribution Models; Urban Transportation Modeling System.

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Trip Distribution Models

Trip distribution models estimate the expected number of trips T_{ij} from an origin i to a destination j . These origins and destinations can be traffic analysis zones in an urban area or points, such as airports, household and employment locations, schools, and so forth. Trip distribution models are used widely in transportation planning as part of the urban transportation modeling system (UTMS). In fact, trip distribution models are one the four model components (that is, steps or stages) of the UTMS.

Taxonomy

The long history of trip distribution models has resulted in different methodological modeling frameworks. Thus, trip distribution models can be

considered as probabilistic in relation to deterministic, aggregated vis-à-vis disaggregated, and static vis-à-vis dynamic models.

Deterministic trip distribution models have been developed as optimization formulations in mathematical programming (for example, as minimum cost models subject to origin, destination, entropy, and cost constraints). Such formulations are adequate to describe overall origin-destination travel patterns when cost or time minimization is the dominant behavioral consideration (for example, among morning commuters going to work).

Additional deterministic formulations have been proposed within the classical microeconomic paradigm of utility-maximizing choice behavior subject to budget constraints. Under various forms of utility functions, the resulting demand function takes the form of a gravity model. Other such efforts have introduced interaction costs (for example, travel time) directly into the utility function. Such approaches require strong assumptions about individual choice behavior and are difficult to test in practice.

More generally, however, traveling from place to place involves a multitude of individual decisions that defy any attempt at deterministic description, to say nothing of prediction. As a result, various probabilistic frameworks have been developed.

One of the earliest models proposed in this regard is Stouffer's "intervening opportunities model," which has been shown to be a special case of a gravity model. Alternative probabilistic approaches employed Luce's theory of individual choice behavior. Additional efforts applied McFadden's multinomial logit model, which can be shown to yield gravity models with exponential deterrence functions—for example, of the form

$$T_{ij} = A_i B_j \exp(-k \theta_{kij}),$$

Another type of random utility approach used Simon's satisficing principle in which individual decisions to interact in space (for example, travel) are modeled by a probabilistic threshold variable depending on relevant measures of spatial separation (for example, travel distance, travel time, etc.).

Probabilistic theories based on statistical equilibrium concepts have been proposed. The essence of the approach is that the most probable state of microspatial interactions can lead to very regular

patterns of macro interaction behavior that are exactly representable by exponential gravity models. It is interesting to note that most trip-distribution models developed are static, implying a shift from one stationary (or equilibrium) state to another. In dynamic contexts, gravity models have been used to describe state transitions in Markov processes.

Disaggregate trip distribution models, also referred to as destination choice models, can be developed as individual choice models (for example, logit models, probit models, etc.) to predict the probability that an individual will choose to travel to a particular destination as a function of individual and destination characteristics.

One of the main issues in this regard is the definition of destination alternatives in the relevant choice sets. This task is more feasible with particular types of trips (for example, shopping trips where a store or a class of stores can be identified). For other types of trips (for example, recreational trips, nonwork trips, etc.), such alternatives may not be easy to identify. In those cases, it may be possible to further disaggregate trip purposes to more elemental dimensions.

Aggregate trip distribution models, on the other hand, do not consider the characteristics of individual travelers and predict the probability of travel between zones as a function of average origin, destination, and origin-destination separation (for example, travel distance, travel time, travel cost, etc.) measures. The most frequently used aggregate trip distribution model is the gravity model, which in its most general formulation takes the form

$$T_{ij} = A_i B_j F_{ij}.$$

The exponential gravity model, in particular, can be written as a logit model. Doubly constrained gravity models, for example, can be viewed as two interlocking choice models; that is, choosing a destination location given an origin location, and choosing an origin location given a destination location.

Estimation

Disaggregate trip distribution models estimate the expected number of trips to destination places using travelers or households as distinct observations, thereby avoiding aggregation bias for the estimated parameters. In addition, disaggregate data at the personal or household level are suitable for market

segmentations where individual observations are classified according to their socioeconomic characteristics, and a separate model estimation for each such classification or market segment. Maximum likelihood estimation methods are used to estimate the model parameters.

Issues that need to be addressed in the estimation of a destination choice model include, first, the generation of relevant destination choice sets of each individual observation possibly by a separate model. In this case, the choice set is a subset of all available destination alternatives from which the traveler chooses the utility-maximizing alternative destination.

The process permits individuals to have different or common classes of destination choice sets for the same trip purpose. In practice, deterministic or random constraints at the personal, household, and societal level are imposed to limit the size of choice sets to manageable levels.

Second, disaggregate trip distribution models generate disaggregate predictions that must be aggregated for use in policy analysis. Alternative procedures for aggregating the predictions of disaggregate models include (1) the summation-integration approach, (2) the classification approach, (3) the naïve approach, (4) the simulation approach, and (5) analytic approaches. Note that inherent in all statistical aggregation procedures is the fundamental trade-off regarding the choice of spatial aggregation units: suitably small to ensure spatial homogeneity but sufficiently large to allow meaningful statistical sampling.

Estimation of gravity models in urban transportation planning is usually done using maximum likelihood methods. This is because the number of origin and destination zones is very large and, consequently, most of the observed flows are zero valued.

In particular, maximum likelihood estimation of Poisson gravity models (in cases where the available observed flows are Poisson distributed) is very robust; its robustness stems from the many types of asymptotic results that establish the Poisson distribution as the unique limiting form for a wide range of interaction processes when the population size increases and the overall influence of each individual interaction decreases. On the other hand, when there are not too many zero-valued observed flows, linear least squares methods may also be used.

Four types of gravity models have been identified: unconstrained, origin-constrained, destination-constrained, and doubly (or origin and destination) constrained. When origin and destination trip totals are not available in the forecast period, the corresponding constraints and the corresponding parameters, which are the Lagrange multipliers (in the maximum likelihood estimation), are dispensed with and unconstrained gravity models are obtained.

Similarly, if only the origin (destination) trip totals are available, the constraints for the destination (origin) parameters can be removed, and origin- (destination-)constrained gravity models are obtained. If both origin and destination totals are available, a doubly constrained gravity model is obtained.

Forecasting With Trip Distribution Models

Disaggregate trip distribution models are developed to predict the destination choice for individual travelers. Because policy decisions affect groups of travelers, or even the entire population of a region, it is important that these models can predict the aggregate travel demand between pairs of destination locations. Methods to aggregate individual predictions are available.

Forecasting methods with aggregate trip distribution, especially gravity models, are also available. Four distinct cases have been discussed: (1) when forecast travel costs are exogenously available, and all origin-, destination-, and separation-based parameters remain unchanged in the forecast period from the base period; (2) when forecast travel costs and separation-based parameters are available from the base period, and destination-based parameters and origin totals are exogenously available; (3) when forecast travel costs and separation-based parameters are available from the base period, and origin-based parameters and destination totals are exogenously available; and (4) when forecast travel costs, separation-based parameters, and origin and destination totals are available.

Application

In the application of disaggregate trip distribution models, it is critical that several types of data are available: (1) traveler- and trip-related attributes that may influence the choice of a particular destination (for example, income, auto ownership/



Trip distribution models are a component of the traditional four-step transportation forecasting model. This step matches traveler's origins and destinations to determine the number of trips going from each original location to each destination. Traffic analysis around busy areas such as the Washington Dulles International Airport, shown here, can determine many factors regarding the design and layout of the airport itself and the surrounding areas.

availability, trip purpose, travel party size, time of day of travel, etc.); (2) attributes related to destinations available to the traveler (for example, travel time and costs, shop type, job category, central business district/city/suburban indicator, etc.). Such data will decide the suitability of model structure (for example, multinomial logit model, nested logit model, etc.).

For example, in a regional application, it may be desirable to estimate the travel demand at prominent destinations. In this case, the overall destination choice may be sequentially estimated by a nested logit model where the “logsums” of the prominent destinations would “inform” the regional work- and nonwork-destination multinomial logit-choice models. In practice, it is not uncommon that the choice of destinations is determined jointly with the mode choice for different trip purposes.

On the other hand, applications of gravity-based trip distribution models are numerous in both passenger and freight travel demand forecasting. In a particular application in freight demand modeling, it was assumed that the behavior of each shipping firm can be considered a very small

interaction process and that the resultant overall interaction process (that is, the realized pattern of origin-destination commodity shipments) can be considered the superposition of all these individual firm-based processes and thus characterized by gravity models. This application obtained an excellent model fit during estimation, as well as small variances and small standard errors of the flow estimates, which provided the basis for measuring the level of accuracy of the origin-destination estimates.

Context-Sensitive Destination Choice

Both the multinomial logit and the gravity model have the “independent of irrelevant alternatives” (IIA) property. In the context of trip distribution models, the IIA property implies a strong form of context-insensitive behavior by travelers, in the sense that the relative likelihoods of choices among pairs of destination choices are independent in the presence or absence of any other destination alternatives. As a result, the variety of models that have been developed to overcome this restriction can be thought to involve a context-sensitive behavior.

Disaggregate trip-distribution models that do not have the IIA property include the generalized extreme value (GEV) class of models (for example, the nested logit model, the paired combinatorial logit model, etc.), as well as other generalizations of the multinomial-logit and probit models.

On the other hand, gravity models can also be generalized to relax the IIA property. One way this is done is by assuming that prominence effects tend to enhance the likelihood that a particular destination location (for example, a specialty store) will be chosen. Such prominence effects are attributable to dissimilarities between choice alternatives.

Another way that gravity models dispense with the IIA property is by assuming that spatial interaction behavior involves a hierarchical interaction process in which a relevant cluster of destinations is first selected (or perceived) by the traveler, and then a specific destination within this cluster is chosen.

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See Also: Destination Choice Models; Freight Transport Models; Gravity Models; Origin–Destination Models; Residential Location Models; Transportation Modeling and Planning Software; Transportation Planning; Travel Demand Forecasting; Travel Model Calibration and Validation; Trip Chaining; Urban Transportation Modeling System.

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Trip Generation Rates and Models

Trip generation is the first step in the classical four-step transport modeling sequence (trip generation, distribution, modal split, and assignment). Its objective is to predict the trips—and more generally the units of measure of movement, like tours—that will be made by the residents of the study area. Although personal trips account for the majority of urban trips (more than 80 percent), trip generation is also a part of freight models.

In principle, this step is very simple. Trip generation usually outputs two sets of trip ends: the number of trips originating in (trip productions) and the number of trips destined for (trip attractions) each of the zones of the study area (also referred to as traffic analysis zones, or TAZ). Personal trip productions are usually determined as a function of socioeconomic variables like income, family size, household structure, and car availability; attributes of TAZ like value of land and residential density; or other (non-residential) land use information like some measure of accessibility.

Personal trip attractions are determined as a function of zonal employment and/or roofed space available for industrial, commercial, and other services. Freight trips are usually determined as a function of the number of employees, the number of sales, roofed area, total area, and so forth. It must be noted that even if it is one of the more used explanatory variables, the explanatory power of car ownership has declined over the years due mostly to its universality.

In order to properly quantify the movements within a study area, a definition of the unit of measure is needed. There is no consensus regarding the definition and/or nomenclature of the unit of measure of movement.

The simplest unit of movement is a stage, which is a continuous movement with one mode (vehicle) of transport. A trip is a continuous sequence of stages between two activities. A journey is a sequence of trips that start and end at the same location. A tour is a sequence of trips that start and end at the home of the relevant person. Trip generation is a generic denomination of models that may use these different units of measure of movement.

Segmentation of Trips

To strengthen the explanatory power of trip generation models, trips are often segmented by purpose (i.e., modeled separately with one model for each trip purpose). This segmentation allows for an easier definition of the relation between the characteristics of individuals or TAZ with the number of trips (e.g., number of workers to explain commuting). Usually, the following purposes are considered: work, education (sometimes segmented further by school level), shopping, social, and recreational, among others. Work and education trips are often considered as compulsory (mandatory) or less flexible, while trips for other purposes are viewed as discretionary (optional).

Another segmentation commonly used is based on whether one of the ends of the trip is located at the home of the trip maker. It is then possible to distinguish between home-based (HB) and non-home-based (NHB) trips. This segmentation allows for two different approaches in the characterization of trip ends for HB trips. In the first one, trip ends are directional. If we take the example of trips to work, trip production for HB work trips, for a given TAZ, consists of the number of trips beginning at home in the TAZ for which the destination is at work somewhere within the study area. Trip attractions, for a given TAZ, correspond with the number of trips having this TAZ as work destination for which the origin is somewhere within the study area.

In the second one, the direction of trips is not taken into account. Trip production is associated with the home end of HB trips (home being the

origin or destination). Trip attraction is associated with the other end of HB trips (this "activity" end being the origin or destination). For NHB trips, the directional approach is generally used and no segmentation by purpose is considered, as these trips only amount to 15 to 20 percent of all trips.

The growing importance of NHB trips casts some doubt on the relevance of HB trip purposes for analysis. For example, if a person drives his or her children to school and then goes to work, an approach in terms of HB trips will only acknowledge the school-based portion and the trip to work will be counted as an NHB trip. The main purpose of the trip, that is, work, is therefore lost. In contrast, an approach in terms of tours retains information on the main purpose of the tour. Given that some trip purposes are more constrained than others, it is possible to assign a single purpose to a tour in a hierarchical manner.

The purpose of the tour is work if this purpose is present among the trips included in the tour. If not, then it is education if this purpose is present, and so on, according to the following hierarchy: work, education, shopping or personal matters, leisure, other.

This definition has two major advantages: it is consistent with the main reason for leaving the home-place and allows for a symmetrization of the matrices of movements for each main purpose, which is important when the model is used for forecasting as matrices are generally symmetries within the whole four-step chain.

It was thus necessary to estimate the maximum number of trips for the period of peak demand. For transit planning, modeling just the morning peak was preferred since the maximum intensity of the morning rush hour is close to that of the evening, and morning traffic is more homogeneous in terms of trip purpose. Trips to work and school predominate and the duration of the rush hour is relatively constant.

In contrast, only the evening peak period was typically used for highway and road planning, as the evening rush hour period has been growing and the share of work/school trips declining in favor of shopping, recreation, and other personal trips. Evolving concerns of planning and socioeconomic evaluation has increased the need for modeling the entire travel day, and even trips occurring on weekends.

Unit of Analysis

In the first modeling studies, trip production and trip attraction relations were established at the TAZ level. This approach was limited because it was possible to introduce only a few (one or two) explanatory variables and because of the challenges of using the modifiable areal unit problem (MAUP) for spatial analysis. Today, trip generation relations are rather established at the household or person level, and then the results are aggregated across TAZ. The first argument in favor of modeling at the household level is that some of the trips are related to the maintenance and usual "functioning" of the household and that these trips are managed collectively at the household level. The second concerns the allocation of resources in terms of income and car ownership, which also takes place at the household level. The third is that models at the individual level have specific problems related to a higher proportion of units of analysis that do not travel.

The benefits usually attributed to modeling trip generation at the person level include the fact that, intuitively, trips are made by individuals, not households or areas. The analysis at the individual level can be undertaken from surveys of individuals (rather than households), which reduces the sample size (in terms of number of individuals to sample) needed to obtain similar levels of statistical accuracy. It also allows the use of telephone or Web surveys, which are often made on an individual basis. It is also possible to include household characteristics among the variables characterizing the individual. Furthermore, in the context of forecasting, some demographic changes are easier to model at the level of the individual household.

Studies comparing the explanatory performance of household- and person-level models suggest that both estimate trip ends at the zonal level with similar accuracy, slightly favorable to the individual-level models. The inclusion of variables related to the household in the individual-level approach gives significantly better results during calibration, but this improvement does not necessarily translate into improved forecasting performance. Some studies have shown that the household-level approach can yield slightly better results in forecasting. Moreover, as most studies at the person level actually use data from household surveys, the assumption of independence of observations usually implied by the models (especially regression

models) might not hold. The choice of the unit of analysis must therefore depend on data availability and data analysis even if the individual level is generally preferred.

Cross-Classification Methods and Trip Rates

Cross-classification analysis (CCA) is the modeling method generally accepted as the simplest and therefore the most commonly used, particularly in the American context. It consists of partitioning the sample of households or persons using one or more socioeconomic variables. It is assumed that the groups thus obtained are relatively homogeneous within each category and quite different from one category to another, in terms of trip-making behavior.

The definition of trip rates is closely related to CCA. Trip rates correspond to the average number of trips per household or person calculated for each population segment. The nonparametric nature of the method allows some flexibility in the choice of explanatory variables as it is not necessary to assume a particular form for the relationship between these and the dependent variable.

The main limitation of the method lies in the requirement of a certain number of observations for each category. The analyst is confronted with a trade-off in which increasing the number of categories results in a greater homogeneity of these, but it also leads, for a given population size, to a reduced size of each class and therefore to less robust coefficients (trip rates). Moreover, the choice of variables for the definition of classes does not always lead to resulting groups having similar sizes.

In order to address some of the shortcomings of CCA, alternative methods have been developed. The best-known of these is multiple classification analysis (MCA). MCA is an alternative method used for defining classes and trip rates. For illustration, it is useful to present the case of two independent explanatory variables. First, an average number of trips per household or person for the entire sample is established (a "grand mean").

Subsequently, using the table of trip rates resulting from the CCA of the two independent variables, a mean trip rate for each row and column of the table is calculated. Then the difference between the grand mean and the mean trip rates for each row and column is calculated. Finally, the new trip rate for each cell is defined by adding to the grand mean

the difference with the corresponding row and column. This procedure limits the problems arising from having too few observations in one particular cell of the CCA array.

MCA itself has, however, a number of shortcomings. For instance, the trip rates obtained are different from those obtained with conventional CCA for all the cells. Moreover, some trip rates might have a negative sign and the usual correction applied is to manually give these a value of zero. This is sometimes problematic as CCA might assign a positive value to the same cells.

Regression Methods

Regression methods have been widely used in transport modeling and are still very common for trip generation models. The core of these methods is that they establish a linear relationship between one or several independent variables and the number of trips (or some transformation of the number of trips) for a given unit of observation (zone, household, person, etc.). Regression methods may vary then by the unit of analysis (which is similar to cross-classification methods) but also by type of model.

The most commonly used method is multiple regression by ordinary least squares (OLS). In this method, the number of trips per unit of analysis, conditionally to the values of the different explanatory variables selected, is supposed to be identical, independent and normally distributed (this is also known as the iid normal errors hypothesis) and the explanatory variables are supposed to be independent (i.e., not correlated).

The main advantage of this method is that continuous and discrete explanatory variables can be used. Its major drawbacks have been extensively described in econometrics textbooks. The relation between the variable to be explained and the explanatory variables is linear and only linear, which eliminates other types of correlation. Regression results are less robust when explanatory variables are correlated among them. The iid normal errors hypothesis is not always observed, which leads to less robust estimates. This method struggles in the presence of units of observation (households or persons) that do not go out of their homes.

In order to deal with some of the limits of OLS, other regression methods are used. These are often

called generalized linear models (GLM). The two main models of this kind that are used are the generalized least squares regression (GLS), which mainly deals with the non-observation of the iid normally distributed errors hypothesis, and the logit models, which allow a higher degree of correlation between explanatory variables and deal better with persons or households with zero trips.

One last type of regression method that is gaining in popularity is the tobit model, which is kind of in-between OLS and logit as it has the simplicity of OLS and the possibility to explicitly deal with persons or households with zero trips.

Toward New Microsimulation Methods Based on Automatic Classification

Traditional trip generation methods (i.e., cross-classification and regression) struggle to take into account a big part of the heterogeneity of urban mobility. The variable to be explained is a number of trips (or a number of a particular unit of measure of movements) and therefore the chaining of activities and, in the case of tours containing non-home-based trips, the main purpose of the tour is usually lost.

Moreover, traditional methods have well-known limitations as pertains to their specification. Regression methods are limited in capturing all the interactions between explanatory variables. Cross-classification techniques allow for a wider treatment of interactions between explanatory variables but they lack an optimal procedure for variable selection.

As computing power has increased, automatic algorithms for segmentation have gained in popularity. Algorithms like CART (classification and regression trees) or CHAID (chi-squared automatic interaction detector) allow for establishing a relation between not only the number of trips but also, for example, the types of tours (where the type of each tour is defined by the sequence of trip purposes it contains) and explanatory variables (continuous and discrete), which are segmented automatically according to their explanatory performance (homogeneity of trip behavior).

Once the segments of population with close mobility profiles have been established, the method can be used for forecasting. It is necessary to generate a synthetic population at the time horizon. For each individual who belongs to a segment of the synthetic population, an individual from the travel

survey belonging to the same sociodemographic segment is randomly chosen and his/her mobility pattern is assigned to the individual of the synthetic population.

The method presents several advantages. It generally allows for more explanatory variables, which therefore generates better performance when taking into account sociodemographic evolution of the population like aging or household structure. The random procedure maintains the diversity of mobility profile among population, which is lost when other methods are used. But like other methods, the main limitation is associated with the hypothesis of behavioral stability among each segment.

Stability of Trip Generation Relations

Given data constraints, trip generation models are usually calibrated with cross-sectional data. For forecasting purposes, the hypothesis is made that the parameters of the models are stable. Research on the subject has shown that while this hypothesis is not too problematic for a forecasting horizon less than 10 years, demographic, societal, and behavioral changes make it difficult to use this hypothesis for a forecast over a longer period.

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See Also: Travel Demand Forecasting; Trip Chaining; Trip Distribution Models.

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Trip Reduction Programs

Trip reduction programs are the result of local, state, or regional government requirements aimed at encouraging the use of transportation alternatives to single-occupant vehicle travel. Such options include ridesharing, public transit, bicycling, walking, and telecommuting.

The majority of trip reduction programs focus on work-related commutes and peak travel times. As such, employers tend to be the chief implementers of trip reduction programs. Some ordinances cover travel reduction related to shopping and other personal reason, and therefore may impose requirements on commercial property owners, schools, or other public service organizations as well. In some cases, local governments are required to develop and implement transportation management measures such as park-and-ride lots, high occupancy vehicle (HOV) lanes, and shuttle services to support trip reduction mandates.

The main goals of most trip reduction programs are the alleviation of traffic congestion and reduction of associated emissions that contribute to air pollution. Some local, state, and regional governments also use trip reduction programs as interim or supplemental solutions to address financial difficulties tied to adding new transportation capacity for growing demand and to delays in implementing transit improvements.

In addition, public concerns about the social and environmental impacts of transportation capacity expansions and pressure to minimize

traffic implications associated with new development in rapid-growth areas have spurred a move toward trip reduction programs in some areas.

Policy Approaches

Trip reduction policies are based on the specific needs of the local, state, or regional area. There is no single set of policies or master program for all locations or situations; rather, a broad range of trip reduction policies and programs exist. Most trip reduction policies, however, fall under one of the following general types.

Local, state, or regional governments may issue policies that encourage but do not mandate that employers provide commute alternatives information and incentives to their workforce. The same policies may require complementary actions on the part of the government to support the initiatives, such as the creation of an outreach program designed to collaborate with interested employers and their employees. The voluntary nature of compliance with these types of policies means that some employers may not wish to engage. Those that do may cease their participation at any time.

Some trip reduction requirements are included as a bargaining element for negotiations as part of larger policy plans, such as those dealing with rezoning or a major public-private development agreement. The practice enables the trip reduction program to be designed to lessen the negative impacts perceived as potential outcomes of a project. For example, the inclusion of trip reduction elements may allay fears about increased traffic congestion associated with a new development project under consideration.

Trip reduction activities are sometimes included as a requirement for developers or employers who choose to accept government financing or incentives. In these arrangements, the local, state, or regional government gains a willing partner in helping reduce traffic congestion and pollution. Similarly, trip reduction measures are sometimes incorporated into the conditions of approval for new development projects.

For example, a construction permit might require the creation of on-site parking spaces for high-occupancy vehicles or an occupancy permit might stipulate a need for an on-site transportation coordinator. These types of project requirements are negotiated on a case-by-case basis.

Requirements affecting all developments and all employers of a certain size represent another category of trip reduction policies. These policies may require enterprises—usually larger ones—to develop and implement transportation management programs such as ridesharing, flexible work hours, or subsidies for users of alternative commuting methods. The programs may be based on incentives, such as preferential parking for car-pools, or on disincentives, such as the imposition of parking fees for driver-only vehicles. Quantitative performance measures, such as achieving a goal of 25 percent of employees actively engaged in commuting alternatives, also may be a component of required programs.

Governments may issue requirements that sufficient public facilities and services be in place before additional development will be approved. In these situations, the policies may call for developers to implement specific types of facilities and services—such as park-and-ride lots at all major housing developments, sidewalks and bike paths, on-site transit pass sales, or rideshare matching—and to attain certain transportation-related performance standards.

In some cases, trip reduction policies may impose impact fees or benefit assessments as a component in the funding of transportation improvements. The funds may be restricted to capital improvements, such as traffic signal equipment, sidewalk benches, or shuttle buses. Sometimes the funds can be used for operating expenses as well, such as those tied to the provision and administration of rideshare matching services.

Multiple trip reduction policies and approaches are utilized in most jurisdictions as a way to secure the broadest participation possible in transportation management among businesses, developers, and the public.

Factors in Effectiveness

The effectiveness of a trip reduction program relies in large part on the scope of the program—voluntary or mandatory, type and percentage of travel affected, types of trip reduction activities permitted—and how performance is measured.

Local governments may be reluctant to impose trip reduction requirements on existing employers and businesses, especially when those entities claim that the requirements are unnecessary and

burdensome. Enabling employers and businesses to develop their own trip reduction plans generally is considered as a more business-friendly, flexible way to gain acceptance.

However, if participation in a trip reduction program is completely voluntary or if enforcement of mandatory programs is lax, the effectiveness of the program relies largely on whether the plan provides accrued benefits for the businesses that choose to participate. For example, when benefits of participation are perceived as nonexistent or minimal, many organizations will simply choose not to participate, and those that do may fail to put sufficient support behind the program or terminate at the first sign of negative impact. Mandatory trip reduction programs are more likely to achieve the intended results.

A majority of trip reduction programs target a subset of overall travel, such as peak work commute times. If the program applies strictly to certain travel, then logically only a percentage of total travel within a jurisdiction will be affected.

Localities that restrict the reach of their ordinances in such a way typically do so to concentrate their efforts and resources on the best markets for trip reduction. With peak-time commutes, for instance, the trips tend to occur during periods of heavy travel and thus tend to be disproportionate contributors to congestion, emissions, and energy consumption. At the same time, they are the trips that are most easily accommodated by mass transit services and ridesharing.

Most trip reduction programs seek to reduce use of single-occupant vehicles and their associated environmental impacts. However, programs that employ strategies such as flextime or nearby remote parking will produce smaller overall reductions than those that facilitate alternative modes of travel or trip elimination altogether, such as ridesharing or telecommuting. The minimization of single-occupant vehicle use is especially important in areas that are attempting to reduce emissions, fuel consumption, traffic congestion, or parking requirements.

The ways of measuring the success of a trip reduction program vary greatly. Some emphasize procedural measurement, such as whether a plan has been developed or implemented. Others focus on specific outcomes, such as employee participation or automobile usage. The latter provides more

meaningful assessment of the true performance of the program or components within the program.

Adoption Characteristics

In designing an effective trip reduction program, it is important to understand the combined effect of the factors that influence travel choices, such as transportation system characteristics, the physical and chronological distribution of travel activities, socioeconomic characteristics of the affected travelers, economic environment, and local business conditions. For the typical trip reduction program, the key factors to consider are the availability and quality of transportation alternatives, standard travel patterns and trip lengths, employee and employment characteristics, and efforts to support the use of commute alternatives.

The practicality of commute alternatives must be considered from the public's point of view because consumers are the ones who must decide whether to switch travel modes or continue solo commuting. The qualities that commuters generally seek in a viable alternative are whether it can compete with the current travel mode in terms of commute time and cost.

Some commuters may be lured to alternatives by other benefits, such as exercise opportunities or the ability to perform other tasks such as reading while traveling, but these factors typically are not as influential in changing behavior as are issues of time and cost. Public transit can offer a reasonably competitive alternative for many commuters, but service restrictions in suburban areas can be a detriment. Bicycling and walking are viable alternatives in some areas, but ridesharing is by far the most frequently promoted commute alternative in trip reduction programs.

Travel patterns and trip lengths are other factors to consider in assessing commute alternatives. Transportation services are generally better, and the number of potential ridesharing matches larger, for trips to and from major employment centers such as central business districts and large office parks. Longer trips offer the most appeal for ridesharing programs, with carpooling being most effective when participants live at least 20 minutes from work. For employees who live within 10 miles of work, bus transit is a realistic travel option. Bicycling and walking are choices for commuters living within three miles of work.

Even when strong alternatives are available, some employees still may not be willing to change their travel habits. The most likely takers for commute alternatives are usually found among employees who are new to a company, new to a location, or have recently moved residences. Those who come from moderate-income households, follow a fixed work schedule, and do not have a guaranteed, free and convenient parking space are also prime candidates. It is much more difficult to reduce single-occupant commuting activities among employees who have been using that method for an extended period of time, are high wage earners, work irregular hours, or are provided free or inexpensive reserved parking.

For those who need a car to meet personal obligations on the way to or from work, such as dropping children off at school or banking, some employers may be able to offer services to offset those needs. For example, some larger employers provide services such as convenience grocers, dry cleaners, banks, and child care. Larger employers are usually better positioned to provide shuttle services, in-house ride-share matches, and similar support services.

Policies and programs that could bolster trip reduction programs include enabling employers to be reimbursed for subsidies for commute alternatives through their company expense accounts and retracting the ability for employees to “expense” parking costs; taxing employees for employer-provided parking and offering greater deductions for utilization of commute alternatives; and providing HOV lanes for buses, carpools, and vanpools and offering preferential parking for pool vehicles in public facilities.

Potential Impact

Realistic targets for trip reduction programs range from a 5 percent to 10 percent reduction in single-occupancy vehicle trips. Larger reductions in peak-period trips can be generated if alternative work hours are permitted and the peak travel time in the area is short. Larger reductions also may be possible if trip elimination strategies such as telecommuting are promoted. Percentage reductions will likely stabilize after initial start-up, so objectives for the trip reduction programs should be revised periodically to ensure they remain as realistic as possible.

While trip reduction programs may help a community remain within certain traffic limits, it is unlikely that the typical trip reduction program

will have a broad-enough reach to substantially alleviate existing congestion. A more realistic objective might be the prevention of further deterioration of traffic conditions in the face of new growth and development.

In terms of reducing emissions, the extent to which trip reduction programs can help depends on their effectiveness in changing modes of commute and on the extent to which they shift travel to less congested periods, when emissions per mile would likely be lower due to fewer stops, starts, and delays.

Implementation of mandated trip reduction programs can be difficult for smaller employers and certain types of businesses, such as those that require a significant number of employees to have a vehicle for their work. Some of those programs require significant commitments of personnel and funding, and demand a great deal of time and resources for maintenance, monitoring, and enforcement.

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See Also: Accessibility and Mobility; Automobile Culture; Bicycle Commuting; Car Sharing; Carpool Programs, Ride Sharing and; Carpooling; Parking Cash-Out Systems; Parking Demand; Traffic Congestion.

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Triple Convergence

Traffic congestion during peak traffic hours is ubiquitously present in almost all metropolitan areas. Despite numerous supply-side interventions (e.g.,

building additional expressway lanes, major arterial streets, and expressways), most metropolitan areas continue to remain congested during peak traffic hours. The principle of triple convergence, first posited by Anthony Downs, explains the persistence of congestion on limited-access expressways (also called freeways) during peak traffic hours.

According to the principle of triple convergence, traffic congestion on freeways during peak hours represents a rough state of equilibrium in which freeways do not offer any travel time advantage over alternative routes. Any freeway capacity enhancement is likely to relieve traffic congestion only temporarily. The freeway will eventually become congested again, and the system will arrive at another equilibrium.

The rationale behind the principle of triple convergence is straightforward. Individuals, as rational decision makers, try to optimize their travel costs. Travel cost has two components: time and money. Different travel modes impose different costs: public transit often costs less than driving in monetary terms, but public transit is usually slower than driving. Hence, depending on how much they value their time, individuals choose different travel modes (public transit versus personal vehicle).

If the time it takes to reach a destination by driving is similar to that of traveling by public transit, individuals may be indifferent to the time cost. Other factors such as monetary cost and/or convenience then become more important determinants of mode choice. By the same reasoning, drivers always prefer the fastest route because it imposes the lowest time cost, all else being equal.

Most automobile drivers choose to take the quickest route to their destination, one that is direct, has highest speed, and is least encumbered with obstacles such as traffic signals and stop signs. Except for trips of a very short distance, in most cases this route includes a freeway. Drivers converge on the freeway from various access points until the freeway is loaded with a much higher number of vehicles than it could carry at an optimum speed—that is, it becomes congested and does not offer any travel time advantage over the alternative routes.

It follows that the commuters could reach their destinations using alternative routes (such as surface streets) in as much time as it would take using the freeway. However, despite the congestion,

many commuters continue to drive on the freeway out of habit.

Congestion on the freeway continues to increase to the extent that the freeway route actually becomes slower than the alternative routes. This prompts some drivers to switch to the alternative routes that are now faster than the congested freeway. Eventually, the surface street routes also slow down as a result of increased traffic volume. This process continues until none of the routes offer any advantage over the alternatives, and the transport network is in a state of rough equilibrium.

During the equilibrium, traffic moves at below-optimal speeds on any given freeway or major arterial street. Despite severe congestion, the freeways still carry more vehicles per hour than the surface streets, simply because they have a much larger capacity.

If the capacity of any congested freeway were to be remarkably increased, say by building additional lanes, congestion on the freeway would be reduced and traffic speeds would rise. Driving on the freeway rather than on alternative routes would once again become more advantageous. This would prompt drivers to begin converging on the freeway in the following three ways (hence the term *triple convergence*):

1. *Spatial convergence*: Commuters who were previously driving on an alternative route start using the freeway
2. *Time convergence*: Commuters who were avoiding congestion by traveling before or after peak hours start traveling during peak hours
3. *Mode convergence*: Commuters who were taking public transit during congestion again start driving to work

This triple convergence continues until the freeway becomes congested again and the transport network reaches another equilibrium. Traffic speeds once again drop to levels much lower than the optimum speed, and vehicles are almost crawling on freeways and streets.

Note that any intervention that leads to increased capacity of the transportation network will lead to triple convergence. Even providing a new rail transit service or augmenting an existing one may not relieve peak-hour traffic congestion. Provision of additional

rail transit service would likely prompt some drivers to forgo driving to work and start taking public transit, particularly if travel times in both driving and public transit are similar. This would create room on freeways once again, triggering triple convergence.

Policy Implications

The principle of triple convergence establishes that capacity expansion of freeways, or building additional road capacity anywhere, will not mitigate traffic congestion permanently. Indeed, it is impossible to eliminate peak-hour congestion from freeways and major arterials by building additional capacity unless the capacity of those roads is increased to the extent that they can carry every single commuter simultaneously at the peak minute. This is quite obviously an unreasonable and unrealistic solution. Although adding roadway capacity does not mitigate traffic congestion permanently, it still produces some social benefits. For example, all else being equal, the duration of the peak traffic congestion is likely to become shorter with additional roadway capacity.

Anecdotal evidence tends to support the principle of triple convergence. Traffic congestion has remained persistent in all major cities throughout the world despite substantial enhancement of the transportation network over the past century. Even substantial investment in rail transit infrastructure in several major metropolitan areas has not reduced traffic congestion.

Indeed, some cities with the world's largest public transit infrastructure are also the cities where traffic congestion is most severe—for example, London, Hong Kong, and Seoul. In the United States, several rail transit systems have been built to address traffic congestion, including the Bay Area Rapid Transit (BART) system in San Francisco, California, and the Metropolitan Atlanta Rapid Transit Authority (MARTA) system in Atlanta, Georgia. However, there is no reliable empirical evidence that traffic congestion has actually lessened in those cities as a result of their investment in rail transit.

This discussion suggests that reduction in freeway congestion—due to any intervention—is not permanent because triple convergence will recreate congestion on freeways. However, one strategy that is not likely to lead to triple convergence, and that therefore would reduce traffic congestion in the long term, is to increase driving costs on freeways

through road pricing. This could be done in two ways: (1) as a fixed toll amount irrespective of the time of day or traffic volumes on the freeway, and (2) as congestion pricing where tolls vary, typically being higher during the peak hours and lower during off-peak hours.

Appropriate road pricing would increase the cost of driving on freeways to the extent that triple convergence would not be generated. Indeed, it may produce the opposite effect: triple divergence. In triple divergence, some drivers take alternate routes (spatial divergence), some drivers start using public transit (mode divergence), and some drivers change their commute times to avoid the rush hour (time divergence).

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See Also: Road Pricing Schemes, U.S. and International; Traffic Congestion; Traffic Demand Management; Traffic Flow.

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Trolleybuses

A trolleybus or trolleycoach is a hybrid between a bus and a streetcar. Like a bus, it runs on rubber tires and is steered by the driver. Like a streetcar, it has trolley poles on the roof that run along two wires suspended above the road, supplying the electricity to power the motor and operate the trolleybus.

The first trolleybuses began operating in 1905 and were seen as a low-cost alternative to streetcars or trams, because they could use the same power supply but without the need for expensive tracks.

At that time, the gasoline-powered bus was in its infancy and fuel was expensive to obtain. There was another detriment, too: The state of roads at the time was poor and the first trolleybuses ran on solid tires, which did not give a comfortable ride—certainly nowhere near as comfortable as a tram. So for 20 years, trolleybuses were a curiosity that was not taken up further.

The impetus that led to the rapid development and uptake of trolleybuses was twofold. First, the first generation of streetcars was wearing out in the 1930s, needing to be replaced. The second reason was the development of motorbus technology, and especially the pneumatic tire, which gave a smoother ride, even on rough road surfaces. This allowed less busy streetcar lines to be converted to trolleybus operation, retaining the capital investment in the power supply system and providing new vehicles at a lower cost than that for replacement streetcars.

There were, however, several downsides. First, even though trolleybuses were lighter than the trams they replaced, they used more electricity because of the much higher rolling resistance of rubber tires on tarmac roads, compared to streetcar steel wheels on steel rails. Substations needed to be reinforced to provide the extra power. The second operational downside was that as the driver could steer the trolleybus over the whole road, for example, to overtake a parked car, this meant the trolley poles were more prone to de-wire and bring the service to a halt while the operator retrieved the poles.

Some cities went for wholesale replacement of trams by trolleybuses. One example was London, where from 1935 to 1940 half of the tram network was replaced by trolleybuses, creating the largest system in the world. Trolleybuses in London were abandoned in 1962, replaced by diesel power when oil was cheap. As in other British cities, London's trolleybuses were double decked with virtually all passengers seated, and a roving conductor collect fares based on the length of journey made. Today there are 358 trolleybus systems worldwide, most in former or presently communist countries.

Bus Versus Tram Systems

The main differences between bus and tram systems is that buses can be steered anywhere on a road, even to overtake a broken-down bus, whereas

a tram has predetermined tracks and cannot run anywhere else in the road.

Proponents and detractors claim the “flexible” bus can be diverted to avoid problems or extended to serve new areas in a city. A trolleybus can obviously do the first, but not the second, without capital investment in overhead cables and electricity substations to supply power. Recently, however, a new generation of trolleybuses has been developed that has small diesel engines and so can operate off the overhead wires for short distances and at reduced speed.

The main problem with buses is that as no two drivers are the same, and often, because of parked vehicles, buses cannot always pull up exactly at the roadside to provide safe and convenient boarding for passengers with physical or mobility impairments. In contrast, trams can always dock at the same place against the stop platform, making safe boarding and alighting for all passengers automatic at every station. The predetermined trackage for trams also means that passengers have smoother rides with fewer jerks than buses.

Market Perception

Ride quality differences between buses and trams mean that potential passengers can differentiate between buses and trolleybuses, on the one hand, and streetcars and other rail systems, on the other. Even where attempts have been made to provide a pseudo tramway service with trolleybuses, for example by using busways, this is unlikely to entice habitual car users.

At the final stage of this development are guided trolleybuses with tracks like trams (for example, the TVR system adopted by Caen in France). Recently, Caen decided to scrap the TVR and replace it with a tramway, claiming it would have been cheaper in the first place. The TVR running on the same part of the road continuously required expensive and regular repairs. The TVR vehicles were expensive to maintain, being proprietary equipment, and had very high power consumption because of the rubber tires.

Many trolleybus systems have replaced earlier tram or streetcar lines, sometimes extended to serve a new suburb, but always with slightly different terminal arrangements. While trams can run in either direction and so only need a crossover between tracks, trolleybuses are unidirectional and



The guided light transit in Caen, France, is an electrically powered guided trolleybus. There are 24 three-section vehicles, guided by a central nonsupporting rail. The network serves a total of 34 stops and a full 40 percent of public transport trips.

require a turning circle at termini or where several routes share the same terminus, and parallel wired lines to allow overtaking.

The majority of the cities that operate trolleybuses today have low levels of car ownership. Should they reach the levels of more developed countries, it is likely that these trolleybus systems will be abandoned, as they have been in most of North America and western Europe. In some ways, trolleybuses represent the worst of both worlds, the poor ride quality and poor image of buses, and an expensive infrastructure to operate.

More Recent Developments

Like diesel buses, trolleybuses have gotten bigger through the use of a trailer section articulated to the main vehicle to create a single vehicle 60 feet (618 meters) long, and capable of carrying 120 passengers, although most of these will be standing.

There are some examples of vehicles with two trailer sections that together make the bus 79 feet long (24 meters), with a capacity of 150 passengers. Such long vehicles have special requirements, especially pulling into and out of stops at the roadside, because the trailing sections do not follow exactly the same path as the front sections and require a very wide "swept path" on curves. This presents

special problems at terminals, where the articulated trolleybuses turn around to start the return journey.

Operation and Infrastructure

Although trolleybuses do not require tracks installed in the road pavement, the overhead line (OHL) is much more complicated for buses than it is for streetcars or trams. For trams, the overhead line is typically electrified at 500 volts to 750 volts direct current (DC), so that different lines can cross each other without any electrical difficulty.

For trolley buses, there are two wires for each direction. One wire will be DC positive and the other DC negative. This means that at junctions, OHL crossings have to be carefully insulated to prevent short circuits that can result in power failures. This is particularly important to prevent a passing trolley head from creating an arc between positive and negative lines, which can damage and weaken the wire and potentially cause a short circuit. Added to this are the dangers of weather. Rain and snow conduct electricity and can cause arcing between positive and negative lines at OHL crossings.

Trolleybus substations that supply electricity to the OHL also have to be provided, and these can be large, depending on the number of vehicles operating in the section at any one time and the power drawn by each. Similarly, the cable connections between the substation and OHL have to be fully insulated to prevent the possibility of short circuits.

Historically, a trolleybus OHL is divided into electrical sections about one-half mile (one kilometer) long. This allows a section to be isolated in the case of a local emergency (for example, a fire in a building on the side of the trolleybus route) and allow firefighters to put up ladders without fear of electrocution.

Trolleybuses were the first electrical transit vehicles to have power regeneration during braking. That regenerated power ideally needs to be used by accelerating trolleybuses in the vicinity. If this is not the case, then the voltage in the OHL can rise to dangerous levels, threatening to break down cable insulation. This led in the 1930s to the invention of the "Hastings coupler," which effectively turned the whole trolleybus OHL system into a single power network, or "ring main." The Hastings coupler is designed to isolate adjacent power sections if the voltage difference on either side becomes too great, for example, if there is a short circuit in one section

and a regenerating trolleybus in the adjacent. At other times, trolleybuses draw power from whichever substation has available capacity, and regenerated power is distributed to trolleybuses on the network.

The major negative side of trolleybuses is the complex of wires in the sky, which can be considered visual pollution. There are ways to make OHL aesthetically more pleasing and less obtrusive. One of these is to support the OHL by span wires fixed to buildings along the road. This avoids the need to have poles along the side of the street, which can create a vision of a forest of poles. Second, the method of attaching the OHL to the span wires can be by simple insulators, thus avoiding a juxtaposition of wires in the sky.

There are people who claim to find OHL along city streets visually offensive, period. One such group campaigned in San Francisco to scrap the trolley coaches to get rid of the OHL. There was a referendum, with the question "OHL or diesel bus fumes?" People voted overwhelmingly in the referendum to retain the trolley coaches.

Network Structure

Because of the complexity of the OHL infrastructure, trolleybus networks tend to be much simpler than flexible buses. This means that network scheduling and driver timekeepers are very important to running a reliable system. This is because trolleybuses cannot pass one another.

Indeed, there are examples from the United Kingdom when trolleybuses were converted to diesel buses and service reliability deteriorated markedly, much to the annoyance of passengers, often providing them with another reason to buy a car and desert transit.

Against this, there are several important environmental advantages to trolleybuses compared to diesel. First, trolleybuses are much quieter in operation, so they can run in streets where diesel buses would create a noise nuisance. In some cities where traffic noise is loud, trolleybuses often have a little chain dangling from the front to create a tinkling sound that can be heard above the lower frequency traffic noise to warn pedestrians and drivers of an approaching trolleybus.

Second, trolleybuses emit no fumes, toxic or otherwise, in city streets, so they can operate in densely developed areas where air quality would otherwise

be a problem. Some cities have implemented a policy of electric transit only in the city center as a public health measure.

Because trolleybuses can accelerate and brake more quickly and smoothly than diesel buses, fewer are needed to provide the same level of service and passenger capacity. Fewer large vehicles have a benefit for road traffic by helping reduce congestion and pollution, provided complementary traffic management measures are implemented to maintain traffic volumes at a steady flow state.

Interchange Stations

Trolleybuses, like buses, are unidirectional, so the provisions required at interchange stations are more complex and land hungry than they are for trams or streetcars. This may not be a problem if the air rights over the interchange are used for commercial or residential development. For trolleybuses, unlike diesel buses, no special ventilation is needed at interchange stations, since no toxic fumes are emitted. In all other respects, interchange stations for trolleybuses have the same or very similar requirements to other transit interchanges.

Walk and Ride

By definition, trolleybus services will operate on urban roads, and most passengers will walk to the bus stop to get on and walk from the stop at the destination, unless it is an interchange and the journey continues on another transit mode, for example, a subway.

Siting trolleybus stops might seem to be an easy planning exercise. Just plant a pole at the roadside, and trolleybuses will stop to pick up passengers. The science of spacing and locating trolleybus stops is well advanced and balances the theoretical with the practical. The aim of siting trolleybus stops is to attract the largest number of passengers by providing the shortest possible travel times consistent with economical operation. In addition, trolleybus stops need to be located where it is safe to stop and start the vehicle, and practical to pull in and out of the traffic stream.

Some cities make this safety part easier by having continuous or nearly continuous bus lanes along the side of the road, from which other vehicles are excluded. If the rest of the road is congested, then trolleybuses will run at the roadside, faster than the rest of the traffic stream.

The key, however, is the dovetailing of trolleybus stops with land use development. This requires knowledge of where people live and to where they want to travel for work, shopping, leisure, and the other activities that are part of life. Knowing where people live is relatively easy, but unless a full transport study is undertaken, determining journey destinations is more difficult.

Routes that have a mixture of compulsory and request stops can be difficult to schedule. There will be a maximum running time needed, if all request stops are made, and a minimum when none are. Fortunately, computer simulation indicates there is a simple solution to this problem: that is to use the average running time, and to make some of the busiest compulsory stops timing points. Should a trolleybus be running early, as when none of the preceding request stops have been made, the driver waits a short while at the timing point to get back on schedule. If the driver is late at the timing point, the trolleybus will depart immediately on the basis that the probability of stopping at all request stops ahead will be small.

By this means, trolleybuses can be kept evenly spaced, so that convoys do not occur. Convoys cause considerable annoyance to passengers when they see three vehicles pass by, and then a very long gap until the next trolleybus arrives. Here the key is maintaining a high level of reliability and even frequency, characteristics that passengers value and without which there will be a strong incentive to quit transit use.

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See Also: Bus Rapid Transit; Buses; Light Rail Transit; Streetcars/Trolleys.

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Truck Drivers, Labor Issues of

The road network serves all the places of production and consumption. Its wide-reaching and flexible nature and its key role in the circulation of freight make it extremely important to global trade, particularly within large urban areas. However, it would cease to exist without the work of those in charge of transporting the goods. Indeed, next to nonmobile handling agents, truck drivers—or truckers in North America, truckies in Australia and New Zealand, and lorry drivers in the United Kingdom (UK)—make up the most important working population in the haulage system. In the United States, the Bureau of Labor Statistics estimated their total number at 2,867,400 in 2010.

Following an overview of the key regulatory features governing truck driving, this entry discusses the tensions that arise from the distinction between driving time and working time and from the social relationships that characterize this profession highly dominated by men. Finally, some perspectives will be drawn in view of the drive toward market deregulation.

In most countries of the developed world, commercial driver's licenses (CDLs) can be obtained from the age of 18. In North America, the Federal Motor Carrier Safety Administration identifies several categories of drivers (e.g., delivery truck drivers, drivers sales workers and heavy and tractor-trailer truck drivers) who must hold distinctive types of licenses defined by criteria such as the gross vehicle weight rating. Similar regulations are applicable in the European Union, including the requirement to undergo a certified training program every five years.

The main task of a truck driver is to make a journey marked by a series of stops between the shippers (for the pickup) and their clients (for the delivery). However, truck drivers represent a heterogeneous group whose daily experience varies according to the type of journey they make. Depending on the destination and the number, distance, and frequency of stops, the journey may last from several hours up to several days or even weeks. For example, as opposed to local drivers, long-haul drivers may spend long periods away from home. Linemen are the only ones who always make the same journey.

Working time is not limited to driving. Time spent waiting, loading and unloading, dealing with paperwork, and so on must also be taken into account. Drivers have to deal with a multiplicity of people who may not always be available, which prevents them from planning their work schedules ahead. The degree of constraint increases with the frequency of stops. Truck drivers thus seek to anticipate the different stages of their journeys so as to devise alternative strategies to cope with unforeseen situations.

While driving time is subject to a number of rules all over the world, this is not always the case with regard to working time. In the United States, a driver may spend a total of 11 hours behind the wheel during a period of 14 consecutive hours. Since 2013, driving is not permitted if more than 8 hours have passed since the end of the driver's last off-duty or sleeper-berth period of at least 30 minutes.

In the European Union, the daily driving time should not exceed 9 hours (twice a week, this may be extended to 10 hours). After driving for 4.5 hours, a driver must take a break of no less than 45 minutes. The weekly driving time cannot exceed 56 hours, nor can the total driving time during any two consecutive weeks exceed 90 hours.

Truck drivers are engaged in two types of social relationships, which both entail some degree of subordination. The first concerns the classical employment relationship between employees (company drivers or wage earners) and their bosses, and the second relates to the contractual arrangements between business entities, including that between owner-operators and independent workers.

In this type of relationship, the two parties are typically shippers on the one hand, and carriers (or forwarders) on the other. Shippers may be farming, industrial, or business enterprises whose production generates merchandise flows (for provisioning and distribution). Forwarding companies are those in charge of transporting shipments for others (a practice known as transport for hire or reward) as opposed to own-account transport companies that carry their own freight. To reduce their inventory costs, shippers reduce or remove their stocks as quickly as possible. Relying on just-in-time management practices, they thus transfer the time constraints of the production process onto forwarding companies.

However, medium-size or large transport companies also increasingly exert pressure on small forwarders by occasionally acting as charterers. This means that they outsource the transportation of their freight to another forwarder, a smaller company or independent owner-operator. They choose to do so because they may be unable or unwilling to meet a demand that is highly exposed to risks or barely profitable, or simply because of insufficient resources.

Consequently, working conditions vary from one type of truck driver to the next. At own-account companies, the organization of work is integrated into the production. Haulage is an integral part of the process of value creation. At companies based on a transport for hire or reward system, the added value stems from freight storage and delivery being achieved within set times. Fluidity is their main objective, and this is heavily dependent upon the driver's ability to adapt to the organizational patterns of the shippers and clients it connects (opening and closing times of the warehouses, availability of personnel at the shipper's, etc.). This requires adjustments of the driver's working and rest hours.

Before the deregulation of road haulage activities, each driver was allocated the same tractor and enjoyed a high level of autonomy. These arrangements were seen as compensation for the flexibility required by the job. But competitive market pressures have led haulage companies to rationalize their activities. They have made their services more flexible by increasingly disconnecting the truck driver from the tractor. At the same time, geolocation systems and other package tracking tools have reduced the advantages that drivers would derive from remote working. Today, management has direct access to a range of information regarding the truck's itinerary, its stops, and whether it is on schedule. It may not necessarily know all the details about difficulties encountered by the drivers, such as traffic conditions or causes for delays at the shipping/receiving places.

Next to the problems of isolation and long periods being away from home, drivers are exposed to several risks. Research conducted in 1987 in France by Patrick Hamelin has shown that the risk of road accidents is correlated with the duration of the work amplitude (from 14 hours and onward, it is 2.5 times higher than under 10 hours of work) and more precisely the number of hours carried

out, and according to the times at which the drivers are at the wheel (at the end of a normal working day and at night). At the same time, the risk of being involved in an accident is doubled when driving during nighttime hours (between 8 P.M. and 6 A.M.). Risk is also present while working on and around trucks (e.g., slipping, tripping, and falling). Accidents can occur when leaving or entering the cab, loading and unloading, connecting the truck tractor to the trailer, or trailer-top operations at clients' premises.

In addition, truck driving also entails a number of long-term health risks. These include musculoskeletal disorders, cardiovascular diseases, hypertension, and sleep disorders. Time constraints and atypical working hours often lead to unhealthy eating habits such as skipping meals or overreliance on fast food restaurants. Moreover, the combination of poor sleeping conditions and the use of drugs to ward off tiredness can lead to hypertension. Finally, constant mobility impedes access to appropriate health care in countries that have failed to develop services for these types of road users.

Since 2010, cabotage, defined by the European Commission as the "national carriage of goods for hire or reward carried out by non-resident haulers on a temporary basis in a host Member State," has been deregulated in Europe, the objective being to reduce the number of journeys made with empty vehicles. But legislative harmony between working and fiscal conditions is still weak. Many national haulage companies fear that they will be outplayed by competitors who enjoy more favorable legislation in their home country.

As a result, truck drivers' working conditions may worsen. Hamelin's research has shown that a way for individual agents to offset the pressure from the institutional and economic environment is to alter their driving behavior. In the UK, they may regularly breach the Highway Code, for example. In fact, this situational behavior is clearly a symptom of a structural phenomenon. Eventually, when the strain and unrest over wages and terms reach a climax, truck drivers resort to industrial action, bringing regional (and in some instances, national) economies to a standstill.

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See Also: Driver Licensing, Commercial; Freight Handling; Truck Inspections and Vehicle Licensing; Trucking, Owner-Operators and; Trucks; Trucking Industry; Trucking Industry, Economics of.

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Truck Inspections and Vehicle Licensing

Trucks are any vehicles designed to carry cargo, and they are divided into light, medium, and heavy trucks by the federal government for the purpose of regulation. Light trucks include pickup trucks and some vans, minivans, and sport utility vehicles (SUVs), even when such vehicles are used mainly for personal transportation rather than transporting cargo. Heavier trucks require special driver licensing; a commercial driver's license is required to drive any vehicle over 26,000 pounds.

Class A licenses allow the driver to drive combination vehicles, including coupled buses; Class B licenses allow the driver to drive single vehicles over 26,000 pounds or commercial-use combination vehicles under 26,000 pounds; Class C licenses allow the driver to drive vehicles that carry hazardous materials or more than 15 passengers, and in most states are issued as both commercial and noncommercial licenses. (Noncommercial Class C licenses include large campers and buses used for noncommercial purposes, for instance.)

Commercial driver's licenses (CDLs) are required by federal law but are issued by the states, which is why some of the specifics (e.g., going above and beyond the federal requirements) vary from jurisdiction to jurisdiction. CDLs are also accompanied

by specific coded endorsements listing vehicle-specific training, such as that for hazardous materials transport, air brakes, school buses, or plural trailers.

Like all motor vehicles, trucks are also subject to regular inspections. The periodicity and nature of the inspection varies from state to state. Emissions inspections are required annually in all metropolitan areas with air quality below federal standards, according to the Clean Air Act.

Safety inspections for noncommercial vehicles vary widely, with some states requiring them only upon registration or transfer of ownership and others requiring them annually or every other year, but commercial vehicles are generally subject to inspections that are more stringent or more frequent. In Hawai'i, for instance, vehicles used by emergency personnel, in public transportation or school transportation, or used as rental cars must be inspected every six months, while personal transportation vehicles are inspected only annually. Pennsylvania, too, requires six-month inspections for most commercial vehicles and emergency vehicles.

Because commercial trucks constitute so much of the regular traffic of highways and other routes, and because their sheer size and weight increases the severity of any accident in which they are involved, licensing to ensure competent drivers and inspections to ensure safe vehicles are two measures to reduce the likelihood of accidents. Other measures include restricting truck travel to designated areas; in 15 states, trucks are restricted to certain lanes of the highway, for instance.

Several metropolitan areas use truck bans or diversions to restrict access, including Los Angeles, California, and Atlanta, Georgia, and many have specific initiatives aimed at unsafe and illegal habits such as shoulder parking. The trucking industry is regulated at the federal level by the Federal Motor Carrier Safety Administration (FMCSA), an agency within the Department of Transportation. Federal law requires annual inspections of all commercial motor vehicles, but leaves states free to require stricter or more frequent inspections. In combination vehicles (such as a truck cab and trailer), the inspection must be performed on both.

Motor carriers—companies employing semi-truck and bus drivers and maintaining fleets of vehicles—are responsible for ensuring that their fleets are inspected, just as private owners of automobiles are responsible for having their automobiles

inspected. The FMCSA imposes a number of other regulations, including the blood alcohol concentration at which a trucker is considered intoxicated, a daily and weekly limit on hours driven, and the types of roads on which they may drive.

Commercial trucks may be randomly pulled over for a safety inspection, or pulled over for an inspection because the officer—of whatever body is given authority to do so in a particular state—believes the truck may be unsafe. Trucks that undergo a roadside safety inspection have met their annual inspection requirement and need not schedule an inspection for another 12 months (unless the state requires more frequent inspections).

The American Trucking Associations has criticized random inspections as a waste of resources, claiming that they prevent few accidents, but consume valuable transit time. The trucking lobby in general has argued that regulations in the trucking industry blame truckers disproportionately for accidents, without sufficiently educating non-commercial drivers. For instance, the FMCSA tracks the number of accidents in which a given trucker is involved and whose record can be impinged by accidents in which he has no share of the wrongdoing.

Throughout North America, the truck safety officials' group—the Commercial Vehicle Safety Alliance or VSA (which certifies vehicle inspections)—conducts an annual three-day safety crackdown called Roadcheck. Roadcheck is held with the cooperation of the FMCSA, the Pipeline and Hazardous Materials Safety Administration, the Canadian Council of Motor Transport Administrators, Transport Canada, and Mexico's Secretariat of Communications and Transportation.

During Roadcheck, trucks are selected for random safety inspections at about 1,500 locations throughout North America. The inspections vary in comprehensiveness, though usually more than half are Level 1 inspections, the most thorough, involving an inspection of the vehicle, the driver, and the cargo. The CVSA estimates that during Roadcheck, 14 vehicles are inspected every minute by 10,000 certified inspectors. In addition to the inspections, Roadcheck is an opportunity for inspectors to circulate information about new or recent changes in regulations.

Inspectors ensure that the driver's seatbelt is in working order and check the load securement of

cargo, the position and cleanliness of mirrors, and the personal state of the driver (to make sure he does not seem sleep-deprived, for instance). Brakes are checked for missing, loose, or cracked parts; audible air leaks; correct air pressure; functioning laps and tractor protection system; and brake system warning devices. Lighting is inspected for operation, color, position, and visibility. Coupling and safety devices, including chains and rope, are checked. Fuel tanks are examined for loose mounting and leaks, and exhaust systems have their mounting and system components checked, while seams and clamps are examined for excessive carbon depositing.

The frames of the cab and trailers are examined for cracks, fatigue and signs of stress, corrosion, broken springs, and missing parts. Tires and wheels are checked for proper inflation, signs of damage or fatiguing such as cuts or bulges, tread health and groove depth, defects in the sidewalls, contact with other parts of the vehicle, missing or broken parts, cracked or bent rims, damaged lug nuts and stud holes, cracked spokes or web, and lubricant leaks. The suspension is inspected for signs of misalignment, cracked springs, loose shackles, cracked or loose bolts, and axle misalignment. The steering wheel is examined by manually turning it to confirm that the tires pivot, with the lash measured and compared against the acceptable level.

Trucks must also be licensed or registered with the proper agency, as with any other street vehicle. Departments of Motor Vehicles (DMVs) are responsible for vehicle registration at the state level and requirements vary considerably. For example, California requires some form of California registration for every commercial vehicle on a California highway, which therefore requires interstate drivers to obtain a registration or trip permit (generally good for four days, but longer permits may be applied for) prior to entering the state.

Several private companies offer these and they are also available from the DMV and at truck stops. Companies operating fleets that enter California register their business with the state through the Unified Carrier Registration system introduced in 2007, and pay a fee based on the size of the fleet. Any company operating commercial vehicles that either operate interstate or transport passengers also registers with the Federal Motor Carrier Safety Administration and is assigned a U.S.

Department of Transportation (USDOT) number as an identifier. Some states require the USDOT number as well.

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See Also: Driver Licensing, Commercial; Light-Duty and Pickup Trucks; Truck Drivers and Labor Issues; Trucks; Trucks, Safety Issues and.

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Trucking, Computer Monitoring Systems and

In order to comply with federal and state regulations, many owners and managers of small trucking companies, as well as those of larger fleets, have invested in computer monitoring systems for their vehicles. Most of the monitoring systems on the market today provide benefits well beyond basic compliance with the law. Vehicle tracking technology makes it possible for transportation managers of municipal, commercial, military, and private fleets to collect and interpret data on their trucks and driver behavior. Information on location, speed, fuel use, extended idling, route taken, and unauthorized use, among other driving aspects, can be continually monitored.

The Department of Transportation and Federal Motor Carrier Safety Administration (FMCSA) enforce compliance with regulations that require all truck drivers to carry a log book recording hours

of work service, including the number of driving hours, resting hours, and the times at which duty changes are carried out. The main purpose of hours of service (HOS) records is to prevent accidents caused by driver fatigue. Compliance with HOS documentation for the FMCSA is built into many of the monitoring systems on the market.

Electronic logbooks with HOS software fulfill government regulations by fully automating the entry, recording, completion, and storage of all required information needed for e-logs, and most commercial trucking companies today run their fleets with computerized monitoring systems. These systems are capable of tracking a variety of data, including weight changes and fuel use in the vehicle.

In collaboration with the trucking industry, the FMCSA has been evaluating a number of onboard safety systems through the U.S. Department of Transportation's Intelligent Transportation System (ITS) program. The monitoring systems that may have the greatest effect on reducing costly and deadly commercial motor vehicle accidents are being investigated further. The types of accidents that account for some of the highest numbers of commercial motor vehicle fatalities and injuries are large truck rollovers, lane departures, and rear-end collisions. Onboard devices may be able to warn drivers in the event of situations that could lead to a collision or accident in time for the driver to take preventative action.

Some of these automatic vehicle monitoring (AVM) technologies include roll stability adviser (RSA), roll stability control (RSC), and electronic stability control (ESC). The first system alerts and advises the driver, while the latter two systems actually intervene in the truck's operations. Rear-end collision avoidance technology includes a forward collision warning system (CWS) and adaptive cruise control (ACC), which both utilize computerized vision-based data acquisition. Adaptive cruise control automatically maintains a safe driving distance relative to the vehicle ahead. Lane departure warning systems (LDWS) monitor vehicle position and movement in the lane of travel, detecting any drift from the norm, and alert the driver.

A Global Positioning System (GPS) receiver is installed in each vehicle along with various sensors, depending on which information is to be collected. For example, a sensor can be placed in the fuel tank(s) to track fuel consumption; this data is collected and transmitted to a central location.

GPS satellites should not be confused with communication satellites used for wireless communications. These are two completely separate satellite networks; GPS satellites are used for location purposes only. Real-time systems then use various wireless networks, typically wireless digital cellular, to communicate the location data. GPS data that is collected in the vehicle, along with any other information collected in the vehicle, is typically sent to a server or central operational area. Fleet managers can then view various data depending on the software they use.

Benefits of Truck/Fleet Monitoring

There are many advantages to using vehicle monitoring systems for trucking fleets. The ability to monitor a fleet anytime and anywhere is integral to successful management. Tracking is commonly used by fleet operators for fleet management functions such as routing, dispatch, onboard information, and security. Tracking capabilities offer visibility over fleets, reducing fuel consumption, automating compliance, and reducing maintenance costs.

With more information available, fleet managers can resolve problems such as excessive fuel use, vehicle depreciation, and error-prone manual logbook reporting by drivers. Cutting fuel costs and unauthorized vehicle use while increasing fuel economy and safety compliance can be achieved by using software that enables fleet managers to assess idling times, harsh-braking events, traffic difficulties, and route mileage, along with possible fuel misuse (such as power takeoff, or PTO) or theft.

Monitoring systems enable managers to control routing situations as they arise by dispatching or reassigning vehicles and drivers to areas where need is greatest. Alerts may be scheduled into systems to manage logistics of geographic or time parameter violations. Driver accountability can improve the productivity and efficiency for trucking companies, as well as overall highway safety. Compliance with federal hours of service (HOS) requirements issued by the U.S. Department of Transportation's Federal Motor Carrier Safety Administration (FMCSA) is built into many of the programs on the market.

Future of Truck Monitoring Systems

One bold idea that has piqued interest internationally is truck platooning. This technology uses convoys of

wireless-linked semi-autonomous trucks, or trucks and cars, in a train led by one commanding vehicle and driver. As an example, the train could include three or four trucks that travel on a highway, all at the same speed and same distance (about 12 feet or 4 meters) apart.

The lead driver, who is specially trained, is in command; the followers are “drones,” in which the drivers may read, watch TV, rest, or perform other tasks. All of the vehicles in a platoon have constant, wireless communication with the other vehicles, and adjustments to speed and distance vary with need. Trailing vehicles are also outfitted with radar and laser to allow them to independently detect obstacles and recognize lane markings.

Tests and demonstrations over the past decade in various parts of the world—Germany, the United States, Sweden, and Japan—have shown that fuel efficiency has improved by as much as 15 percent or more due to vehicle drafting. It is thought that platooning and its associated technology could eventually maximize the number of vehicles on the road, while reducing the number of accidents. One of the most advanced demonstrations was undertaken by the European Union–funded SARTRE (which stands for Safe Road Trains for the Environment) project, funded by Volvo. This project explored the use of mixed-vehicle caravans and covered 6,200 miles (10,000 kilometers) of road.

In February 2013, additional platooning road tests were performed in Tsukuba City, Japan, conducted by researchers from the semi-governmental New Energy and Industrial Technology Development Organization (NEDO). Trucks were equipped with automated steering systems and automatic vehicle-following systems. The trucks exchanged information via an inter-vehicle communications system. Many transportation planners believe that platoon formations may ultimately accommodate the heavy freight volumes that are anticipated in high-density corridors between growing urban and commercial areas.

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See Also: Emerging Technologies; Intelligent Vehicle Highway Systems; Truck Drivers, Labor Issues of; Trucking Industry; Trucking Industry, Economics of; Trucks; Trucks, Safety Issues and.

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Trucking, Owner-Operators and

Traditionally, the trucking industry comprises a high proportion of owner-operators. Driving an average of 2 million miles in their careers, owner-operators are self-employed commercial truck drivers or small businesses that operate trucks for transporting goods and materials to manufacturers, businesses, and retailers.

In the United States, the trucking industry can be divided into three categories: company driver, independent contractor/owner-operator, or independent owner-operator. Company drivers, who are hired by a company to drive a company-owned truck, are employees of the company. Owner-operators can be split into two distinct groups, independent contractors and independent owner-operators.

Independent contractor owner-operators own the truck they drive. They are financially responsible for all personal and truck expenses, including fuel and tires. The owner-operator leases onto a company that finds loads for the driver. Essentially, they dedicate their truck, equipment, and driving skill to that company, but maintain a level of self-employment. The owner can refuse a load but cannot take work for any other companies. This type of arrangement provides more flexibility to the owner of the truck and, in addition, is beneficial in securing work and providing a degree of certainty over earnings.

On the other hand, independent owner-operators own at least one truck, but they can also own hundreds or thousands of trucks. An independent owner-operator is classified as a "motor carrier." The independent owner-operator can employ a driver to pull his/her trailer, but the owner has

the responsibility for all aspects of the business, including finding the loads for transportation and staff and maintenance costs. In terms of proportions, the number of independent owner-operators working under their own authority is increasing, although it represents less than half of all owner-operators.

There is some confusion with lease companies over the status of independent contractor owner-operators. This concerns the nature of the legislative duties the company has toward them, which would increase significantly were they considered to be employee drivers and enable the owners to benefit from the protection of basic labor law.

In New Jersey, legislation has been created, which, if passed, would establish penalties for trucking operations in the drayage and parcel delivery business for knowingly misclassifying drivers as independent contractors. This would define the



The trucking industry in the United States transports large quantities of raw materials, finished goods, and works in progress over thousands of miles. This mode of transport is an essential service to the American economy. The owner-operators of these big rigs are represented by the Owner-Operator Independent Drivers Association (OOIDA). The organization actively works to affect state and federal laws regarding the trucking industry.

relationship as employer-employee rather than a contract-based relationship. Many owner-operators oppose this type of measure, arguing that if they wished to work for a particular company as an employee, they would already be doing so, and that it destroys the purpose of owner-operating by lease.

There are also a pair of bills under consideration in Washington State's House of Representatives. HB 1440, which has been approved by the House Finance Committee, presumes an employer-employee relationship exists when companies use independent contractor owner-operators. Consideration by the full house is imminent. To add to this, in March 2013, a Californian court ruled that Port of Long Beach truck drivers working for SeaconLogix, Inc., were employees and not independent contractors.

Over the decades, owner-operators have had to contend with many challenges. The latest, referred to as "the great purge of 2008 and 2009," resulted in a decline in owner-operators of 28 percent. This reduction to the trucking industry was a product of the recession and the lowering demand for products and materials as spending declined.

One researcher has argued that inexperienced or new owner-operators are most susceptible to succumbing to the challenges posed by business and fiscal management and organization. Those who make it through the early years, though, are more business savvy and resilient to change. This stands these owner-operators in good stead for future changes affecting the trucking industry, including increasing fuel prices and equipment costs and increasing haulage demand.

Trucking has been a highly regulated industry since the 19th century, when prices and competition became regulated by the federal government as a means of, at the time, protecting the railroad industry from road haulage competition. The Motor Carrier Act 1935 required all new truckers to apply for a Certificate of Public Convenience and Necessity. Emerging companies found it extremely difficult to get a certificate.

Certified trucking companies were required to file tariffs (rates) with the Interstate Commerce Commission (ICC) before they became effective. These tariffs were then made public. If another trucker, regulated water carrier, or a railroad protested the proposed tariffs, these tariffs were usually suspended and investigated for legality. As the

ICC's grip on trucking companies tightened, those wanting to enter the market found that the easiest way to do so was to buy an existing trucker's certificate.

By the 1970s, this had resulted in a commercial market being created in the certificates that entitled trucks to carry goods on certain routes. These regulatory measures reduced competition, raised prices, reduced productivity, and generally created inefficiencies for carriers, which often were unloaded for the return part of their trip due to lack of authorization for haulage.

Congressional enactment of the Motor Carrier Act (MCA) of 1980 reduced the federal oversight of trucking by the ICC and made it easier for a trucker to secure the necessary certification and authorization to operate. The MCA eliminated many restrictions relating to the commodities that could be carried, the routes that could be used, and the geographical region that could be served. It also encouraged truckers to make independent rate filings with even larger price changes.

The MCA also authorized truckers to price freely within a "zone of reasonableness." This meant that truckers could increase or decrease rates from current levels by 15 percent without challenge. As a result of the partial deregulation, the number of licensed carriers rose sharply while the commercial value of operating rights dropped.

Owner-operators are represented by the Owner-Operator Independent Drivers Association (OOIDA). It is the international trade association representing the interests of independent owner-operators and professional drivers on all issues that affect truckers. Of particular focus to the OOIDA is securing equality and fairness, promoting highway safety and responsibility among all road users, and promoting a high level of efficiency and productivity for all operators. There are more than 150,000 members across all U.S. states and Canada. Collectively, these members own and/or operate more than 240,000 individual heavy-duty trucks and small truck fleets.

The characteristics of owner-operators are surveyed by the OOIDA. The 2012 survey found that the male population dominates the owner-operator segment of truckers, with just 3 percent being female. The average age of owner-operators is 54.

This is consistent with current concerns within the wider trucking industry regarding the forthcoming

shortages of drivers in a recovering commercial market because of the advancing age of drivers and also the work conditions. The level of technology differs between owner-operator groups, with those leased onto a company more likely to have satellite tracking such as Global Positioning System (GPS) for messaging and communication (23 percent) while just five percent of those working under their own authority have this type of technology.

Trucks with a classification of 7 or 8 make up 60 percent of those owned and operated. However, there is a tendency within the owner-operator sector to continue driving the present truck rather than investing in a new truck, mainly as a result of the price of new trucks, which has escalated. There are health and safety, environmental, and efficiency implications in holding onto trucks for a longer time rather than replacing them with newer models that offer more sophisticated technologies, fuel efficiencies, and features such as automatic transmission.

Benefits of owner-operating are largely for the owner and driver. The trucking industry is forecasting a shortage of drivers in the United States of over 110,000 by 2014, citing reasons including long working hours and aging vehicles that demand more driver attention and skill (because, for example, of manual gearboxes and the absence of satellite technologies), and the number of owner-operators is rising in anticipation.

Owner-operation provides independence and self-determination in relation to the choice of loads hauled, the destination of the work undertaken, and the schedule of that work. It is also widely considered to offer greater earning potential and greater resilience.

The disadvantages of owner-operator trucking are that it requires discipline on the part of the owner, business management and organizational skills, and the development of a good image within the sector. All responsibility for marketing, networking, finding loads, and maintaining and servicing the truck, as well as keeping paperwork (including logbooks and invoices) falls to the owner-operator.

The degree of autonomy that owner-operator status offers is an attractive prospect, but it is under threat from legislators seeking to identify independent contractor owner-operators as employees rather than contractors. This is widely rejected by the drivers.

However, the upswing in the global economy is paralleled by increasing numbers of owner-operators functioning with authority. With the volume of road haulage expected to increase consistently over the upcoming years, the future is starting to look bright for motivated and disciplined owner-operators.

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See Also: Truck Drivers, Labor Issues of; Trucking Industry; Trucking Industry, Economics of; Trucks.

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Trucking Industry

The trucking industry, also referred to as the transportation or logistics industry, involves the transport and distribution of commercial and industrial goods using commercial motor vehicles (CMVs). It provides an essential service in the majority of economies by transporting materials, equipment, products, and personnel over land.

Since the advent of the automobile, trucks have superseded rail in many countries across the globe as the primary mode for the transportation of goods and materials. The ability of trucks to go where there were no tracks resulted in the favoring of road haulage over rail and water.

Today the significance of the trucking industry in the United States and the role it has in the economy is summarized in the expression: "If you bought it, a truck brought it." In fact, the U.S. trucking industry transports 69.5 percent of all commercial freight. This equates to 11,712 million tons and \$9,075,000 million in value. By comparison, rail is responsible for 10.2 percent of inland haulage activity, and water transport for 8.6 percent, according to 2012 data from the Bureau of Transportation Statistics.

The main reason for the dominance of road haulage is the accessibility and door-to-door service available from the trucking industry, which can make transportation of goods faster, more reliable, convenient, and cheaper (in part because of a reduction in handling).

Rail still plays an important role in transporting bulk quantities of cargo over long distances, but it is the trucking industry that hauls this cargo from the most proximate railroad stop to its ultimate destination. As an industry, trucking is characterized by small businesses, with 93 percent of interstate motor carriers operating 20 trucks or less.

As well as being the predominant mode of inland haulage in the United States, the trucking industry employs 10 million people, which equates to one in every 15 people working in the country in jobs that relate directly to trucking. Within this figure, there are 3.46 million truck drivers working directly for the trucking industry in the United States.

Truck drivers are persons employed as the operators of a CMV. The Federal Motor Carrier Safety Administration (FMCSA) defines a CMV as a single or combination (truck or truck and trailer) vehicle with a gross weight of 10,001 pounds (4,536 kilograms) or more, or a vehicle used to transport hazardous materials in quantities requiring the vehicle to be marked or placarded under the hazardous materials regulations. In order to legally operate CMVs, drivers require a commercial driver's license (CDL). This requires undertaking advanced and specific training on handling, maintaining, and understanding CMVs.

The FMCSA, a division of the U.S. Department of Transportation, regulates the majority of aspects of the trucking industry, with the Federal Highway Administration handling mainly the construction and maintenance of national and state highways. This includes the hours-of-service regulations and rules relating to the safety of interstate commercial driving.

The hours of service (HOS) regulations govern the hours of service of commercial drivers. These rules limit the number of daily and weekly hours truckers may drive (Part 395.3 and 395.5), as well as the roads and highways they may drive upon. These laws are designed to protect the general motoring public by reducing accidents caused by driver fatigue.

The HOS regulations limit driver hours to 11 hours of actual driving within a 14-hour period, after which he/she must rest for 10 hours. The rules do not explicitly require that a driver must sleep. Drivers are required to keep track of driving hours in a logbook, which is a legally defined form.

The logbook contains a grid outlining the 24-hour day broken into 15-minute increments. The driver must specify where and when he/she stopped between driving shifts, what duties were performed, along with the driver's name, truck number, company information, and other information. The driver must present the logbook to the FMCSA for inspection when requested.

Log books may be replaced with electronic on-board recorders or tacographs, which electronically record the driver's hours. Most individual long-haul drivers average from 100,000 to 110,000 miles driving per year. Regional and city drivers average 48,000 miles behind the wheel, according to American Trucking Association data from 2007.

One of the main challenges presently facing the trucking industry in the United States is driver shortage. This is particularly a problem for long-haul trucking, with an estimate of a 110,000 driver shortfall by 2014. Reasons for this shortfall include the demographics of drivers, many of whom are approaching retirement age. Age, coupled with the nature of long-haul driving, such as the long hours and periods away from home, the average earnings in comparison to other industries, and the dangerous nature of the work, no longer make trucking as attractive a career as it once was.

In terms of health and safety in the trucking industry, workers experience the most fatalities of all occupations, accounting for 12 percent of all worker deaths. Approximately two-thirds of fatally injured truckers were involved in highway crashes. Truck drivers also have more nonfatal injuries, including strains and sprains (50 percent), fractures, cuts and lacerations, soreness, and pain.

These types of injuries are often caused by unloading the goods transported or in the maintenance of

the truck. It is not only the drivers who are exposed to risks of harm to health and injury but also occupants in other vehicles (including other truckers), pedestrians, and cyclists.

The Drive to Increase Efficiency

The trucking industry has in recent years fallen victim, along with other industries and sectors, to the economic downturn and recession. Small trucking companies have struggled in difficult times to get business as volumes of cargo slipped along with reduced demand and supply need. This, coupled with rising gasoline prices, has driven many companies to reconsider their business model, vehicle fleet, and systems of operation, and to increase productivity in order to improve their competitiveness.

The need to increase productivity and achieve greater economies of scale in a quest for efficiency and profits has led to a variety of technological developments, all of which offer efficiency and cost savings. Improved fuel efficiency and alternative fuels of vehicles is a result of regulatory requirements on the automotive industry, which is changing the fleet composition.

Likewise, new materials, virtual reality simulators, advanced aerodynamic designs, increased efficiency engines, stability control systems, virtual dashboards, real-time Global Positioning System (GPS) monitoring, efficient routing software, and tire pressure in-cab monitoring may be products of the need to improve safety, but they all have a positive effect on efficiency, although they have an up-front cost implication.

Satellite communication has led to increased communication and productivity within the trucking industry. The drivers communicate with their dispatcher who is normally responsible for determining and informing the driver of pickup and drop-off locations, and GPS satellite navigation units enable drivers to concentrate on the road and dispense with paper maps.

Similarly, digital satellite television allows greater choice of television programs for drivers during their off-duty periods, which may improve the allure of long haul driving. The transfer from manual transmissions, which require greater skill and driver concentration, to automatic transmission, in trucks reduces driver fatigue, improves the lifetime of internal gears, reduces the risk of accidents, and increases fuel efficiency.

These developments have increased the productivity of company operations, saved time and effort of drivers, and provided new, more accessible forms of entertainment to truckers who often spend long periods of time away from home, making long-haul work more appealing. In the future, trucks may drive themselves and deliver their cargo to their destinations and be completely monitored at all times through the use of robotic technologies.

The advent of the Internet has revolutionized the trucking industry. It helps companies explore new business opportunities and advertise their service to a wider, more diverse population, and it also enables increased productivity. Furthermore, conducting business transactions in a virtual environment can produce efficiency savings of around 15 percent in comparison to traditional paper transactions.

The most recent developments in the trucking industry relate to the introduction to market by Cummins, a leading engine manufacturer, of CMVs capable of making long runs on natural gas. The cheap supply of natural gas from shale gas extraction means that the investment in this technology would pay for itself over the midterm, particularly with oil prices continuing to rise. Indeed, estimates suggest that the natural gas engines would save truckers \$1.50 per gallon. Furthermore, natural gas burns cleaner than diesel fuel, reducing emissions.

However, until the network of supporting infrastructure emerges that makes natural gas refueling widespread, adoption of these engines will be sluggish. The Federal Energy Information Administration projected that if enough filling stations were built and economic conditions were right, sales of heavy-duty natural gas vehicles could increase to 275,000 in 2035, equivalent to 34 percent of new vehicle sales, from 860 in 2010.

European Trucking Industry

In the European Union (EU), the trucking industry, referred to as either road haulage or heavy goods transport, bears close resemblance in character and composition to that of the United States. In terms of contribution to inland haulage, according to the 2010 statistics from the European Commission Eurostat, freight moved by road in the EU accounted for 76 percent of all freight transportation. This is a 3 percent increase from 2000.

Rail transport in 2010 accounts for 17 percent, compared to over 19 percent in 2000 (Eurostat).

Some states, namely Cyprus, Iceland, and Malta, rely wholly on the trucking industry for the supply and transportation of goods. However, in Latvia, road haulage accounts for only 26.5 percent of freight movement, as opposed to rail transportation, which dominates freight movement at 73.5 percent.

In most countries in Europe, freight transport mainly consists of private companies, and most of these companies are small, with between 65 percent and over 95 percent of the companies having nine or fewer employees. Of course, there are differences between the European countries. The economic recession has led to a decline in the number of companies in freight transport by road, but those companies remaining are considered to be smarter, leaner, greener, and more resilient to future economic change.

While there is little indication of a decrease in reliance on the trucking industry in favor of other modes of freight transport, it is apparent that the industry is recovering from difficult economic circumstances. In the longer term, the crisis may be considered as a necessary step in the transition toward sustainable transportation.

Trucking companies are starting to realize the business benefits associated with implementing more robust environmental and safety measures. These benefits include reducing staff turnover (retaining industry knowledge and skills), widening markets, improved company image, and greater flexibility to adapt to change.

Indeed, companies such as Procter & Gamble are turning where possible to companies with natural gas trucks in their fleets. As more companies seek to “green” their supply chain and reduce their carbon footprint, the trucking industry needs to ensure they remain attractive and capable of competing with alternate modes of transport.

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See Also: Green Fuels; Smart Cars; Truck Drivers, Labor Issues of; Trucking Industry, Economics of; Trucks, Safety Issues and; Vehicle Emissions Standards.

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Trucking Industry, Economics of

The trucking industry is an important part of America’s economic foundation and trucks still transport the most freight in the United States, although the industry encountered hard times in the first decades of the 21st century. According to 2012 U.S. Department of Transportation (USDOT) statistics, the transportation industry comprises more than 10 percent of the approximately \$1.4 trillion U.S. gross domestic product, and 82 percent of the money spent in the United States on transportation is spent in the trucking industry. Truck drivers haul 71 percent of all freight moved throughout the United States.

The Journal of Commerce reported some positive trucking industry indicators after the industry suffered significant losses in freight volume from 2008 to 2009. In 2012 revenue increased in the trucking industry and it enjoyed a spike in demand for both long-haul and regional truckers and was firmly on the road to recovery. Long-haul truckload and regional less-than-truckload carriers found a balance in supply and demand and many abandoned chasing unprofitable freight. In its forecast report “U.S. Freight Transportation Forecast to 2023,” the

American Trucking Association (ATA) predicted that overall freight tonnage is expected to grow by 21 percent by 2023, and revenue is expected to increase by 59 percent during the same period. The report stated that the trucking share of total tonnage will increase by 2 percent to 69.6 percent by 2023. Trucking's share of freight revenue will increase from 80.9 percent to 81.7 percent by 2023. Despite positive signs of recovery, the trucking industry still faces several challenges in 2013 and beyond to sustain and expand its growth, challenges that include deregulation and a shortage of truck drivers.

Trucking Economics

The trucking industry is a cyclical part of the economy made up of companies that use tractor trailers to ship goods to customers, who are mostly commercial businesses. Most trucking companies own and operate the vehicles in their fleets, although some do lease them. They make most of their money with domestic shipments, because overseas transportation requires air or sea shipping. The trucking industry tends to be a barometer of the U.S. economy. During an economic upswing, customers ship more goods, anticipating stronger business conditions, and a decrease in trucking demand could signal the beginning of an economic slump.

Major expenses affecting the profitability of trucking companies include labor costs, fuel, operation expansion, and fleet improvement costs. Labor costs significantly impact earnings in the trucking industry because trucking companies need a substantial roster of qualified drivers and freight handlers. Drivers are often in short supply, increasing competition for qualified drivers and the need for the trucking companies to offer competitive wages and benefits to attract the best employees.

Union and nonunion employees also present difficult economic choices to trucking companies. Some trucking companies employ union workers who have strong negotiating leverage and present the risk of labor strife. Nonunion workers come with lower labor costs but sometimes are not as skilled or dependable. Other major labor-related costs include pension expenses and workers compensation.

Trucking companies must also carefully manage fuel expenses. Lengthy trips, heavy loads, and large engines create high fuel costs for tractor trailers.

Most diesel fuel costs are passed on to customers through surcharges, but if fuel prices rise quickly there can be a lag in recouping related outlays that hurt a trucker's short-term profitability. Most trucking companies rely on surcharges instead of long-term fuel contracts.

Various ways that trucking companies finance operating expansion and fleet improvement include cash flow, common equity, and/or debt, depending on the cost of each source. Sometimes a trucking company may assume a heavy debt burden to complete a merger that may offer greater market coverage. Some trucking companies can build cash reserves over a business cycle, and without any pressing capital investment needs, they can reward investors with a big one-time dividend or stock buyback.

The trucking industry bristles with cutthroat competition, because customers have an array of choices, including privately held carriers and companies outside the industry like air and railroad freight organizations. Trucking companies strive to provide excellent customer service to encourage repeat business and to develop close company-customer relationships. Price competition is also fierce and trucking companies usually operate with narrow profit-loss margins.

Truckload and less-than-truckload companies make up the two primary segments within the trucking industry. Truckload carriers load a trailer with large cargo from one customer, usually in the same truck and usually bound for a single destination. Less-than-truckload companies load a trailer with small amounts of cargos from several different customers bound for different delivery destinations. Trucks carrying less-than-truckload goods may stop at multiple terminals and goods can be transferred from several different trucks before reaching their destination. Both types of trucking companies have an established network of terminals and distribution centers across the country.

Seasons affect the trucking industry, with all trucking companies generally experiencing increased demand during the holiday shopping season. Less-than-truckload companies may experience high demand in the middle of the year because of a decreased need to transport large amounts of the same kind of freight. Business usually slows for both truckload and less-than-truckload during the first half of the year because of weather disruptions.

To retain a competitive edge and satisfy their customers, trucking companies must maintain a large collection of tractors and trailers—sometimes numbering in the thousands—and they must upgrade their fleets often, generally every five years for tractors. Frequent upgrades help curb maintenance expenses, since older vehicles require more upkeep and increasing stringent Federal environmental standards compel trucking companies to buy newer, more efficient trucks. New fleets also help attract better qualified drivers during tight labor markets.

Trucking companies must also adjust fleet sizes to match current economic situations, decreasing the number of trucks in operation during downturns to avoid excess capacity. When the truck supply exceeds the demand, trucks produce less revenue per vehicle and other negative numbers.

Economic Fluctuations

With the advent of paved roads in the 1930s, trucking gained a foundational foothold in the United States economy and the construction of the Interstate highway system in the late 1950s and 1960s solidified the economic importance of trucking. Regulation and containerization also helped shape the trucking industry. Congress passed the Motor Carrier Act in 1935, granting the Interstate Commerce Commission the authority to regulate trucks and drivers involved in interstate commerce by granting operating permits, approving truck routes, and setting tariff rates. Since the tariff rates were the same for all trucking companies, price wars were infrequent.

Congress created the USDOT in 1967, and it has had an important impact on the trucking industry. The USDOT oversees trucking requirements like braking and driver licensing standards, maximum work hours, and the safety fitness of interstate carriers. The Motor Carrier Act of 1980 partly deregulated the trucking industry. The decade after deregulation ushered in fierce competition in the trucking industry, with hundreds of new companies and less civility and more intense competition between the leading trucking companies.

By the end of the 1980s, one-third of the 100 largest trucking companies had gone out of business, destroyed by the fierce competition. Trucking companies found it increasingly difficult to operate with union drivers because union drivers earned at

least 35 percent more money than nonunion drivers. New companies were created to operate with nonunion drivers or independent contractors to reduce operating costs.

The Surface Transportation Act of 1982 set uniform size and weight limits for the nationwide trucking industry, stipulating that trucks using interstate highways could not weigh more than 80,000 pounds. The Carrier Reform Act of 1994 reduced the time for customers to file an overcharge claim. By the end of 1995, additional legislation had essentially deregulated the trucking industry and, because of the changes in federal law that preempted the states from regulating the intrastate activities of interstate carriers, many states either deregulated or significantly eased the economic controls over truckers operating solely within their borders. Congress abolished the Interstate Commerce Commission in 1995 and established the Surface Transportation Board (STB), an independent unit operating within the Department of Transportation. The STB administers the remaining regulatory functions for the trucking industry.

The year 2000 turned out to be an unsettled one for the trucking industry, featuring high fuel prices, battles over U.S. taxes, and plummeting new truck sales, but despite the problems the market created more freight and activity for truckers. The fall of 1999 through the spring of 2000 saw the entire trucking industry face a falling of used-truck prices, threatening to undermine the economic health of the nation's fleets, truck manufacturers, and truck finance companies.

Companies bought up low-mileage and used trucks and tractors to try to avoid buying new trucks with the 2002 engines. A flood of good, low-mileage tractors overwhelmed the market and depressed prices to the lowest levels in years. Under accounting rules, the falling value of their massive investments in equipment left about two-thirds of North American trucking companies nearly bankrupt. Bankruptcy filings were widespread and the equipment issue was even more important than escalating fuel prices and driver shortages.

The U.S. economy again stagnated in 2003, and fuel prices and insurance costs pirated a chunk of profits from trucking's bottom line. According to the Department of Energy, the average price of a gallon of diesel fuel in the United States soared to a new record of \$1.51. In 2003, at least 5,000

trucking firms went out of business, and as the hard economic times pushed trucking fleets out of business, trucking capacity declined. Many fleets sliced their operating ratios, which show a company's expenses as a percentage of its revenue, during the year. Operating ratios indicate profitability with an operating ratio of 100 showing a break-even company. An operating ratio of 85 was the best in the trucking industry. When the economy finally rebounded, trucking fleets raised rates as shippers scrambled to find carriers to move their goods, but mergers and acquisitions were the primary moving force behind changes in the trucking industry during 2003.

New driver hours of service rules took effect on January 4, 2004, which effectively reduced on-duty time for drivers and increased the time a driver had to take off between shifts. Many carriers were forced to increase driver pay to recruit and retain drivers in 2004. Demand for drivers was high and the supply limited. The American Trucking Association reported that in the third quarter of 2004, large truckload line haul driver turnover reached a new all-time high of 121 annualized percent.

In 2005, driver turnover remained high, with less-than-truckload turnover at roughly 40 percent and long-haul package truckload driver turnover running over 100 percent. Bulk liquid driver turnover reached over 60 percent. The driver shortage across the U.S. trucking industry ran over 100,000 in the second quarter of 2005.

In 2006, there was heavy pre-buying of trucks and tractors in anticipation of the new 2007 engines and fuel standards. The 2007 trucks and tractors were costlier and averaged fewer miles per gallon. The national average price of diesel fuel reached \$2.745 per gallon through September 2006.

In 2009, over 3,000 trucking companies, mainly small companies and owner-operators, went out of business. After a modest economic recovery in 2010, truck manufacturing surged during 2011, rising from 49,000 in the first quarter to 77,000 in the fourth quarter. The trend reversed in 2012, beginning near 75,000 in the first quarter and ending the year producing just 55,000 units in the fourth quarter.

Twenty-First-Century Economic Challenges

The challenges that the trucking industry faces in the years ahead include federal regulations like new hours of service rules that, if enforced, could create

capacity strains on trucking. As capacity tightens, companies try to expand their sustainability initiatives and shippers turn to intermodal rail in traditional trucking lanes.

The popularity of rail transportation also will continue to challenge the trucking industry to find alternative environmentally friendly fuel sources that offer cost savings in the long run. Although freight tonnage is expected to increase by 21 percent by 2025, the trucking industry must remain competitive when pricing freight services in order to retain a steady level of business and growth.

A sustained truck driver shortage could present a significant challenge to the industry, if the U.S. economy grows at a greater pace than anticipated. The Department of Labor reported that in February 2013, when retail and manufacturing grew steadily, the trucking industry added 5,700 jobs. When it began to slow in March, trucking companies cut 6,900 positions.

The Commerce Department reported that home sales increased 1.5 percent in the spring of 2013, with high levels of demand pushing property values up. Construction firms building more new homes create a demand for lumber and other building materials that need to be transported across the country by trucking companies.

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See Also: Economic Development; Transportation, Economics of; Trucking Industry; Trucks; Trucking, Owner-Operators and.

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Trucks

Trucks are road vehicles larger than a car that are designed for hauling heavy, bulky, or numerous items. In Europe, trucks are referred to as commercial vehicles. Truck design varies according to the intended purpose or freight to be carried; trucks are classified as light, medium, heavy, and very heavy.

Many smaller trucks are manufactured as a single vehicle with a cargo container area, such as a pickup truck. Larger trucks may be built as a single unit for a particular purpose (such as a tow truck, tractor, cement truck, or backhoe) or customized around what is called a chassis cab, which is a truck with a cab and a set of rails that can be specialized depending on the apparatus added to the rear (for example, dump truck bed, camper unit, or containers for various uses).

Many heavy trucks, known as tractor trailers or semi-trailer trucks, have two (or more) separate parts, including the towing engine (also called a rig, cab, or tractor) and a trailer, which, once again, is designed for a specific purpose or use (for example, a tank for fluids, large box container for ocean shipping, specialized container for carrying live animals, etc.)

Trucks usually have diesel-powered engines because of the greater demands placed on the engine, and these engine's greater efficiency and longevity. However, gasoline variants are common in smaller trucks, particularly in the United States. Automatic rather than manual gearboxes are becoming increasingly commonplace in trucks operating in the United States, whereas manual transmissions are more popular in other countries.

Trucks are normally built on a ladder frame, referred to as a chassis in Europe. Chassis are constructed of steel symmetrical C-shape beams or tubes linked by cross members to which the running gear, engine, gear box, axles, wheels, steering, body work, and internal fixtures are mounted.

In the United States, trucks are classified by the U.S. Department of Transportation (US DOT), into eight classifications: Groups 1 through 3 are light trucks, Groups 4 through 6 are medium-duty trucks, and Groups 7 and 8 are heavy trucks.

Light trucks, which are the most popular, are frequently used for either private travel or recreational uses. Medium trucks are generally used for short-haul trips, and larger trucks, with their

greater payload, can transport bulky or heavy loads on long-haul journeys.

Each classification sets specific standards for vehicles, such as requiring only a standard driver's license to operate Class 1 through 6 vehicles, while Class 7 (with weights from 26,001 to 33,000 pounds) and Class 8 trucks (33,001 pounds and above) require special skills and a commercial driver's license.

The classification of the truck determines the cost of vehicle registration fees and taxes, and higher categories also require specific inspection and safety standards to be met. The largest trucks generally require more qualified drivers; for this and taxation purposes, trucks are segregated into various classifications based on gross vehicle weight, or the maximum operational weight of the vehicle fully laden with fuel and driver.

In Europe, like the United States, the larger-sized vehicles require greater legislation and attract greater taxation. The size of commercial vehicle an individual can drive is dependent not only upon what driving qualifications the individual has but also on when they took the driving qualifications. This means that individuals having taken the standard car test before 1997 are capable of driving a single unit truck up to 16,500 pounds or a combination truck and trailer up to 18,100 pounds.

For those qualifying to drive after 1997, the limit on truck size they may legally drive without further training is up to 7,700 pounds and 9,350 pounds, respectively.

The 7,700-pound-class, mostly van based, is the most common. The second most popular class of trucks in Europe is the 16,500-pound single-unit truck. Drivers of these vehicles tend to be older and not to have any formal additional driving qualification over and above the standard car license. Truck-and-trailer combinations up to 97,000 pounds are generally the largest truck allowed on most roads in Europe and tend to mainly be used for long-haul transportation.

In Australia, the heavy-duty-truck sector is the most popular, equating to 16 percent of the market. This is followed by the light-truck sector (12 percent of market), comprising vehicles up to 9,920 pounds. The light-truck category requires no further formal driving qualification. Vans dominate in the Australian light-sector market, but single-unit/chassis trucks are also common.

Single-Unit Trucks

Single-unit trucks/chassis cabs, or rigid trucks, are manufactured with the area behind the driver's cab exposed. This allows the vehicle's owner to build or specify from a coachbuilder the body work best suited for the type of cargo the vehicle is intended to carry. Once the body is fitted on these chassis cabs, they are then referred to as "rigids."

In Europe, classification of trucks is governed by European Union (EU) law and national legislation in member states; for example, the Road Vehicle (Construction and Use) Regulations 1986 in the UK. Single-unit trucks (SUTs), referred to as "chassis cabs," come in a number of size and weight combinations. Two-axle commercial vehicles can be up to 39,650 pounds and are generally used for short hauls and urban loads; three-axle vehicles are limited to 57,320 pounds, and four-axle chassis cabs have a maximum weight load of 70,500 pounds and can run up to 40 feet in length.

In recent years, three-axle vehicles have become increasingly common, particularly for medium-distance work, because they offer greater efficiency, with more miles per gallon (mpg) than their counterparts, including semis and articulated vehicles.

In the United States, SUTs are trucks that are used for general hauling over short distances. Trucks with two axles are used in urban areas and have a maximum weight of 40,000 pounds. SUTs with three axles have a maximum weight of 50,000 to 65,000 pounds. SUTs with five or more axles have a maximum weight of 70,000 pounds and are used to carry the heaviest of loads, such as construction and building materials.

Tractor Units

Tractor units, or fifth-wheel trucks, have an exposed chassis to the rear of the driver's cab, but rather than a specific body being bolted on, a coupling link is mounted on the rear chassis that allows a semi-trailer to be attached. A semi-trailer or "semi" is a trailer with its front axle or set of wheels missing because the weight of the trailer is borne by the tractor unit while it is being transported.

Rather than a set of road wheels at the front of the semi, the trailer has a large steel pin, known as the "kingpin," that slots into the coupling link on the tractor unit, taking a large proportion of the trailer's weight and allowing the trailer to pivot from the tractor unit. The chief commercial advantage of the



This road train in Australia is considered one of the world's longest; road trains are especially suited to conditions in Australia. The trailer arrangement is B-double towing two tri-axle trailers. These large road trains are also known as turnpike trains.

semi is that a truck can be used to transport one trailer while another one is being loaded. In addition, in the event of a breakdown, the loaded trailer can be simply attached to another tractor unit to continue its journey.

In both the United States and Europe the tractor and semi is the preferred combination for heavy-load trucks. In the United States and Australia, these trucks follow the car convention of having the engine and hood out front beyond the cab and are known as "conventional trucks." These offer improved ride comfort for truckers because the longer a vehicle's wheelbase, the less choppy the ride, and improved aerodynamics offer greater fuel efficiency over their European counterparts.

These conventional tractor units have a single forward axle with two wheels, and two rear axles with two to four wheels on each axle. This is where the truck garners the name 18-wheeler, because it has a total of 18 wheels, including the trailer. It can haul a variety of different trailers, including flatbed trailers, enclosed trailers, or tanks.

In Europe, heavy-load tractor units are normally three-axle tractor units with a cab-over-engine design often called "forward control." The principal benefit of this, as opposed to a forward axle with a bonnet/hood beyond the cab, is to allow a longer trailer, because the overall vehicle length is limited by law to 54 feet (16.5 meters). In addition, trailer wheels on European semis are single as opposed to

double-wheel axles. These “super singles” reduce rolling resistance, which improves fuel mileage. Typically, these combined tractor-and-semi vehicles have a gross weight of up to 97,000 pounds and are limited to a maximum motorway/freeway speed of 56 mph.

“Road trains,” “turnpike trains,” or tandem trailers consist of more than one semi-trailer or a single-unit vehicle towing a trailer or dolly (that is, a small trailer with fifth wheel to which a semi-trailer is connected). These are the largest trucks on highways, although they are used less often than traditional semis because of their tendency to sway or fishtail, their longer required braking distance, and the fact that the entire load cannot be detached from the towing vehicle when it is towed by a single unit truck.

In Europe, such combinations can be driven on any road (unless stipulated otherwise) up to a maximum length of 61.5 feet (18.75 meters). Their weight remains restricted to a maximum of 97,000 pounds. The largest variants of road trains can be found in Australia, where a relatively spartan rail infrastructure, great spans of distance to cover, and low population density make road trains an ideal transport solution; one large road train is capable of making the journey that would otherwise require several traditional tractors and semis.

Trailer Types Vary by Function

Truck bodies and trailers are products of the different needs they fulfil. Some of the more common trailer types include the following:

- *Dump trucks*: These have a large open topped container that extends upward on a hydraulic arm. This is used to pick up, haul, and easily unload dirt and gravel.
- *Garbage trucks*: These have hydraulic crushing arms that compact waste.
- *Boom trucks*: Designed to lift or elevate an item or person, these trucks have an arm-like crane boom mounting on a bed behind the truck cab. Boom trucks are used by construction workers to build homes and by utility companies to string cable wires.
- *Flatbeds*: These are made up of a chassis fitted with a platform body on which goods are carried. Cargo is secured on the deck with ropes or sheeting
- *Curtain-siders*: These have a fixed, roofed frame with a flexible curtain fixed to both sides of the frame. They are ideal for carrying pallets that require protection from the weather. Curtain-siders provide easy access to the load for efficient loading and unloading, but have less security than box-bodied vehicles.
- *Box bodies*: These trucks are comprised of a rigid body with solid sides and have solid rear-opening doors or roller shutters.
- *Temperature-controlled*: These are box bodies made of insulated material with a refrigerator unit attached. They are designed to carry temperature-sensitive loads such as chilled or frozen products. The cooling unit is powered by either the main engine or a separate engine.
- *Luton peak bodies*: These are box vans with an additional section over the cab for holding any loose cargo or other tools. They are often used for furniture transport and removals.
- *Road tankers*: These have a permanent tank fitted to the chassis for the transportation of liquids, gases, or powders.
- *Teardrop trailers*: Designed with a curve the whole length of the semi-trailer, they can return a 10 percent savings on fuel over a conventional box semi-trailer.

Recent developments, such as the teardrop trailer, have concentrated on increasing fuel efficiency and a lowering of emissions. In Europe, laws on emissions standards for engines adopted in 2011 establish targets for the reduction of emissions from vans and heavier commercial vehicles, mainly through tailpipe emission limits. Similar laws are increasingly taking effect with more stringency and consistency in the United States. Coupled with a compelling business case to reduce emissions of trucks and increase efficiency, this means that greater focus is being placed on how technology can improve truck efficiencies, reduce carbon and other greenhouse gas emissions, and improve road safety, all of which enhance the competitiveness of road haulage in a period of economic transition.

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See Also: Trucking, Owner-Operators and; Trucking Industry, Economics of; Trucks, Safety Issues and.

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Trucks, Safety Issues and

According to U.S. Department of Transportation (USDOT) statistics, overall traffic fatalities decreased in 2011 for the second consecutive year while truck crash fatalities increased, especially in the truck occupant category, which recorded a 20 percent jump. The Federal Motor Carrier Safety Administration (FMCSA) reported that the estimated 2 million or more tractor-trailers operating in the United States represent 4 percent of all registered vehicles, but they are involved in 8 percent of all fatal collisions each year. These statistics underscore safety issues with large trucks, which pose risks to passenger vehicle occupants and truck drivers themselves. These safety issues that the trucking industry has addressed with varying degrees of success include driver health issues, especially driver fatigue, vehicle conditions, and tandem trailers.

Truck Industry Safety Issues

One of the biggest trucking industry safety issues for the public is traffic tie-ups with the attendant consequences of missed appointments, missed deliveries, missed planes, and people late for work. Truck accidents are a bigger problem to tackle, especially when spill materials have to be cleaned up or towed away. The Insurance Institute for Highway Safety, which has been studying truck accidents for decades, estimated the costs of a single accident—a tanker flipping over while hauling 8,000 gallons of gasoline on part of the Washington, D.C., beltway in May 2011.

Damages, cleanup, police and fire services, and road repairs totaled \$571,789, not to mention the inconvenience for thousands of drivers.

The Insurance Institute for Highway Safety pinpointed 14 proposals to improve truck safety, including requiring anti-lock brakes and discouraging the trend toward larger trucks that began with the 1980 deregulation of trucking. Deregulation inspired a price war that drove down profits and required trucking companies to increase productivity to survive. With increased productivity, the same drivers had to haul larger trailers and heavier cargos.

More than 95 percent of the trailers produced were 45 feet long or less before deregulation, but by 1986 more than one-half were more than 45 feet long and another one-third were the 28-foot-long trailers used in pairs as tandems, according to the Truck Trailer Manufacturers Association. Now the trucking industry trend is triple trailers and Insurance Institute statistics show that tandem trailers are up to three times as likely to be in crashes as other big trucks because of sway and stability problems. The institute is also seeking tougher licensing rules for truckers.

Brakes

Brake Safety Week is part of the Operation Air-brake program jointly operated by the Commercial Vehicle Safety Alliance (CVSA) and the FMCSA and part of an international effort to prevent truck and bus crashes to save lives throughout North America. According to a recent large crash causation study, brakes were a factor in nearly three of 10 commercial motor vehicle (CMV) crashes.

During annual Brake Safety Week inspections in the fall of 2012, the CVSA reported that in September 2012, one out of seven of 21,255 vehicles were placed out of service because of brake issues and brakes have been cited as a factor in 29.4 percent of commercial motor vehicle crashes. Stopping distances for trucks and buses are longer than for passenger cars and they increase significantly with many of the brake violations that are uncovered during the September brake inspections.

Underride Guards

Federal law requires underride guards, metal bars running the width of the trailer and fixed by two posts mounted underneath the tail lights, on nearly all 18-wheeler tractor-trailers. When they work, the

bars prevent a vehicle from sliding underneath the trailer and crushing its passengers during an accident. In a new study, the Insurance Institute for Highway Safety (IIHS) has found that the under-ride steel guards installed on the back of tractor-trailers often buckle and break and even the steel guards meeting federal safety standards can fail in low-speed crashes.

National Highway Traffic Safety Administration (NHTSA) rules, effective in 1998, required lower and wider guards on new trailers, but they did not apply to many of the heavy trucks used on the nation's roads, so the IIHS is petitioning the agency to require stronger underride guards and mandate them for larger trucks and trailers.

Tandem or Twin Trail Trucks

The Surface Transportation Act of 1982 contained a little-known and little-discussed provision that effectively overrode all state laws banning tandem or twin trailer trucks on the highways. Although some states ban tandem rigs on turnpikes and other highways, federal law stipulates that they are permitted on every interstate highway and sections of primary roads that the U.S. secretary of transportation mandates. The trucks and their truckers also must be allowed access to fuel, repair, terminal, food, and lodging facilities, even the ones located in old and congested cities like Philadelphia and Boston.

Opponents of the tandem trailers contend that they are more frequently involved in fatal accidents, with a 1982 NHTSA study determining that in an accident involving a passenger car and a tandem trailer truck, the car passengers are 29 times more likely to be killed than the truck driver. Other critics object to the additional weight that could damage roads as well as endanger travelers, and others point out that although a truck operator is required to apply for permission to haul loads heavier than 80,000 pounds, these permits are easy to obtain and they fear that gross weights may routinely climb to 95,000 pounds and beyond. They say that economically distressed states enforce weight limits loosely and opening up new roads to tandem trailers make, it easy for truckers to dodge state scales.

Driver Health

Truck drivers appear to have the freedom of the open road, but the reality of their occupation is

that their freedom has stringent restrictions. *The International Hazard Data Sheets on Occupations* highlights the occupational hazards that truck drivers face, including the high statistical probability of highway accidents because of their long hours on the road, injuries like sprains and strains from loading and unloading goods on and off the truck, and hauling hazardous material cargoes. The Centers for Disease Control and Prevention and the National Institute for Occupational Safety and Health (NIOSH) recognize that truck drivers are at an increased risk for many specific health problems such as depression, heart attacks, cancer, obesity, sleep apnea, high blood pressure, and diabetes.

In a 2007 study, the *Journal of the American Dietetic Association* estimated that 86 percent of the approximately 3.2 million truck drivers in the United States are overweight or obese for reasons including long work hours and a sedentary lifestyle. Eighty percent of truckers have unhealthy eating patterns because of limited choices of healthy food at truck stops, fast food diners, and vending machines. Irregular snacking and sporadic sleep habits also contribute to their obesity, as do lack of exercise and long work hours and tight deadlines. Truckers often have little or no health insurance and limited access to health care. The Department of Transportation has established Convenient Care Clinics for truckers across the United States, but they are scattered and difficult to find. Health care costs are higher for obese truckers, placing a greater financial demand on the trucking industry. Truckers themselves contribute to their job stress by pushing themselves to the limit to adhere to schedules and neglecting their health on the road. The life expectancy for truck drivers is 61 years, 16 years less than the average.

Fatigue and Hours of Service Rules

Almost 30 percent of commercial truck drivers have a version of sleep apnea, and driver fatigue is a health issue that affects the entire trucking industry. U.S. Department of Transportation surveys reveal that 65 percent of truck drivers report that they often or sometimes feel drowsy while they are driving and nearly half of truck drivers admitted that they had fallen asleep while driving. To complicate the issue, the wages for many truck drivers depend on the miles they drive, and trucking companies also increase their profits when their drivers

cover more miles. This pressure for mileage creates a system that encourages drivers to push past their fatigue limits.

Before the 1980s, few rules establishing the number of hours a truck driver could drive without a rest period existed, and the rules that were on the books were not consistently enforced. Since the 1980s, the federal government has set forth a number of rules addressing the issue of truck driver fatigue in an attempt to make roads safer. The FMCSA established hours of service regulations. These regulations specify how many hours a trucker may drive without taking a rest, how long a driver must rest before driving again, and how many hours a trucker may drive in a week's time. Under the old rules, drivers could work up to 82 hours in seven days, but in 2011, the rules were modified to permit drivers to work up to only 70 hours in seven days. There is an 11-hour per day limit with 10 hours off mandated after the weekly shift. Companies allowing truckers to work beyond 11 hours may be fined up to \$11,000 and individual drivers up to \$2,750, but this law is minimally enforced.

Despite the hours of service rules, the number of tractor-trailer fatality accidents is still climbing, with the National Highway Transportation Safety Administration reporting that in 2011, the number of people killed in large-truck crashes rose 1.9 percent, and the number of truck accident fatalities involving people not riding in the trucks increased 19 percent.

A major shortcoming of the hours of service rules is that drivers themselves report their hours on the road in written logbooks. The majority of drivers are honest, but it takes just one fatigued trucker illegally driving an 18-wheeler to cause a catastrophic accident.

Regulating Trucks and Drivers

In May 2013, the Truck Safety Coalition, safety and labor advocates, and Senator Frank Lautenberg (D-NJ) and Representative James McGovern (D-MA) supported the Safe Highways and Infrastructure Preservation Act (SHIPA), which would freeze existing federal truck size and weight limits, close loopholes that allowed overweight trucks to operate, and establish an enforcement program to ensure accountability. A poll that Lake Research Partners conducted for the Truck Safety

Coalition (TSC) showed that 68 percent of Americans opposed heavier trucks, with 88 percent overwhelmingly opposing paying higher taxes for infrastructure damage from heavier trucks.

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See Also: Deregulation; Driver Licensing, Commercial; Truck Drivers, Labor Issues of Truck Inspections and Vehicle Licensing.

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Tunnels, Safety and Security Issues in

Tunnels are a cost-effective traffic engineering method allowing roads or railways to traverse difficult terrain such as mountains, waterways, or congested urban areas while mitigating environmental impacts. Tunnels have historically been key components of automobile, mass transit, and train transportation systems. When roadways emerged as the main avenue of transportation of both passengers and commercial goods in the mid-to-late 20th century, tunnel construction and usage increased.

The complex infrastructure and typically heavy usage of tunnels, however, present a number of safety and security issues that must be addressed. Tunnel fires have historically been one of the most severe safety issues, while the potential for terrorist

incidents has recently begun to receive more concern. Other tunnel safety and security issues include hazardous materials transportation, ground collapses, floods, and gas leaks or explosions.

Types of Tunnel Safety and Security Issues

Tunnel safety and security issues arise in all phases of a tunnel's life, from design and construction through maintenance and operation. Tunnels are by their nature confined spaces with one entryway and one exit. Therefore, incidents or accidents that occur within a tunnel have the potential to result in serious structural damage, injury and loss of life, environmental damage, and/or transportation disruptions. Traffic accidents within tunnels, such as the highly publicized crash that claimed the life of England's Princess Diana in 1997, also present unique challenges.

Tunnel safety and security issues begin to be addressed during the planning, design, and construction phases. The fact that tunnels are constructed underground or beneath bodies of water increases the risks and safety needs inherent in construction.

Tunnel construction necessarily involves disturbances to the rock or soil due to excavation, leading to the potential for ground collapse. Water intrusion can result in flooding, weakening of the soil, electrical equipment malfunctions, and other safety concerns. Other workplace safety issues include noise, lighting and/or visibility, atmospheric conditions, the use of heavy machinery and explosives, and the potential for dangerous fumes, fires, and unplanned explosions.

Fire is one of the most lethal, and therefore most studied, issues involving tunnel safety. More frequent use of tunnels has given rise to more actual and potential tunnel fires, as well as the resulting damage and loss of life.

Tunnels generally have only two entry/exit points, which increases the difficulty of getting firefighters and equipment to the scene and the ability to evacuate people inside. In addition, the confined space of a tunnel also increases the potential for superheated flashovers; concentrates smoke, fumes, flames, and heat radiation; reduces visibility; and hinders escape and rescue.

Hazardous cargo is another significant and growing tunnel safety issue. Incidents involving the transportation of hazardous materials threaten

human life, tunnel infrastructure, and the environment, in addition to traffic flow disruption and economic losses.

The transportation of hazardous material cargo has historically received less attention than other tunnel safety issues. Thus, the regulation of hazardous cargoes in tunnels shows considerable variation both within and across local, national, and international levels, but it is a subject that tunnel risk management experts must take into consideration.

The rise of terrorism risks has been heightened in the wake of such highly publicized incidents involving transportation as the September 11, 2001, terrorist attacks in New York City and Washington, D.C.; mass transit bombings in London; and a sarin nerve gas attack in a Tokyo subway. These have raised public awareness of transportation security issues, with bridges and tunnels seen as among the more vulnerable potential targets.

Security solutions involving tunnel operations include limiting tunnel access and ensuring the proper identification of employees working in tunnels, whether construction or maintenance crews, toll operators, or others. Types of terrorist threats include arson, bombings, the use of vehicles as weapons, and the release of chemical, biological, or radiological agents.

Tunnel Hazard Mitigation

Tunnel safety and security, as well as risk management, center on the protection of structural elements, human life, and vehicles and their material cargo, as well as protecting the role of tunnels in the transportation network. Preventive measures are common to mitigate safety and security threats. Tunnel inspections help determine structural conditions and identify potential risks. Human elements such as employee information and training are also important. Many tunnel operators establish emergency response plans and first-responder training to enhance tunnel safety systems in preparation for an actual emergency.

Tunnel safety and security measures are often mandatory as well as voluntary. Many local, state, and national regulatory agencies, such as the U.S. Occupational Safety and Health Administration (OSHA), provide workplace safety regulations to govern worker safety during tunnel construction, operations, and maintenance. Worker safety guidelines or regulations can include adequate ventilation

and atmospheric monitoring procedures, and the availability of oxygen, escape routes, and safe refuges in the event escape is not possible.

Emergency ventilation, lighting, power sources, and communications systems are basic components of most tunnel safety and security systems. Tunnel communications systems are vital to both tunnel safety and security. Modern tunnel communications systems often encompass monitored surveillance equipment, such as security cameras and closed-circuit television (CCTV), as well as communications equipment such as radios and telephones. Communications systems are also designed to allow continued functionality in emergency conditions and to prevent their use by non-authorized personnel.

Fire safety systems rely on fire detection and alarm systems, designated fire lanes, and fire suppression methods such as sprinklers, fire hydrants,

and fire extinguishers. Many modern automobile and truck interiors are designed with fire-resistant materials, while tunnel equipment, such as cables, are often fire resistant or fireproof. Tunnel drainage systems to prevent or control leaks and floods include surface drainage, sump pumps and drainage pipes, and the identification of areas vulnerable to leaks.

Tunnel safety is further enhanced through the inclusion of strategically placed emergency egress points and escape routes to these points, such as walkways. These routes must be well lit and clearly identified by emergency markings and/or signage to be effective in reduced-visibility conditions. Alcoves may be provided for disabled vehicles, as well as areas wide enough for vehicles to turn around, if necessary.

Scientific and industry organizations have shown increased interest in studying tunnel safety



This photo from the U.S. Federal Emergency Management Agency shows a mock-up of a subway car used for tunnel and subway safety training at the Center for Domestic Preparedness in Anniston, Alabama, on September 5, 2012. The four-car training facility provides sample scenarios that include a tunnel collapse and the aftermath of an explosion from an improvised explosive device. Rescuers practice extricating victims and dealing with the potential release of hazardous chemicals or biological materials.

and security issues, as well as risk management. Numerous studies and recommendations, as well as meetings such as the International Symposium on Tunnel Safety and Security (ISTSS), have resulted. Although safety and security measures add cost to tunnel construction and operation, these costs are offset by reduced risk and the avoidance of the human and monetary costs associated with accidents, terrorist attacks, or other potential hazards.

U.S. tunnel security underwent extensive changes after the terrorist attacks of September 11, 2001. The Department of Homeland Security (DHS) identified tunnels as a vulnerable part of the transportation system's critical infrastructure. Security changes were designed to reduce terrorist accessibility, reduce their appeal as targets of opportunity, and reduce the potential for serious damage or loss of life if tunnels became the target of terrorism or natural disaster.

Changes included new engineering design standards, the Resilient Tunnel Project to limit water flow in breached underwater tunnels, and the Blast/Projectile Protective Measures and Design and Unified Blast Analysis Tool projects to identify structural weak points and create advanced mitigation measures. DHS also sought to identify and close illegal underground tunnels used to smuggle

drugs and illegal immigrants across the U.S./Mexico border.

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See Also: Highway Tunnels; Terrorism, Transportation Systems as Targets of; Traffic Engineering; Transit Tunnels, Design and Construction of.

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University Transportation Centers

The University Transportation Centers (UTC) program is run by the U.S. Department of Transportation with the mission of establishing centers for transportation studies at American universities to advance transportation expertise and technology in the varied disciplines that comprise the field of transportation through education, research, and technology transfer activities. UTCs receive federal funding to help the government develop a critical transportation knowledge base through research covering a wide range of transportation-related issues and to educate the next generation of transportation leaders.

The education promoted by the UTC program is multidisciplinary and experiential, with a commitment to diversity in faculty, staff, and students, including involvement by students at all levels of study from undergraduate to postdoctoral and professional programs. UTCs work with regional, state, local, and tribal transportation agencies to help find solutions to challenges that directly impact their communities and affect the efficiency of the nation's transportation system.

The program defines six basic goals as part of its mission statement: (1) provide experiential learning in the context of a multidisciplinary program of

transportation education; (2) increase the number of students, faculty, and staff who are drawn to transportation programs at the undergraduate, graduate, and professional levels; (3) engage students, faculty, and staff who reflect the increasingly diverse United States; (4) develop an objective process for reviewing transportation research conducted by transportation centers; (5) support an ongoing program of peer-reviewed transportation research; and (6) make research readily available to potential users.

The UTC program was first established in 1987 in order to improve the country's competitive prospects in the international transportation industry at a time when Japan and (then West) Germany's improved tech sectors posed a threat to industries in which the United States had traditionally been dominant or a leading figure.

Originally allocated funds by the Surface Transportation and Uniform Relocation Assistance Act to establish transportation centers in each of the 10 federal regions, the UTC program was reauthorized in 1991, 1998, and 2005, each time expanding the number of UTCs to over 60 national, regional, Tier I, II, and III centers.

In 2011, efforts to eliminate congressional earmarking reduced the number of centers to just 22 for fiscal year 2012. In 2013, the Moving Ahead for Progress in the 21st Century (MAP-21) transportation bill authorized \$72.5 million for each of the fiscal years 2013 and 2014 for up to 35 competitive

grants for UTCs. These newly authorized centers are organized by research focus around one of five strategic goals: Economic Competition, Environmental Sustainability, Livable Communities, Safety, and State of Good Repair.

The grants were to be divided among five national UTCs (one for each thematic area) with an award of \$3 million each; 10 regional UTCs with an award of \$2.75 million each; and up to 20 Tier I UTCs with an award of \$1.5 million each, though actual awards made for FY 2013 were somewhat less due to federal budgetary constraints.

The new centers established by the UTC program are the following:

National UTCs

- *Economic Competitiveness*: University of Maryland, National Center for Strategic Transportation Policies, Investments, and Decisions
- *Environmental Sustainability*: University of California, Davis, National Center for Sustainable Transportation
- *Livable Communities*: Portland State University, National Institute for Transportation and Communities
- *Safety*: Carnegie Mellon University, Technologies for Safe and Efficient Transportation Center
- *State of Good Repair*: Rutgers, the State University of New Jersey, Center for Advanced Infrastructure and Transportation

Regional UTCs

- *Region 1*: Massachusetts Institute of Technology, New England University Transportation Center (Safety)
- *Region 2*: City University of New York, University Transportation Research Center (Economic Competitiveness)
- *Region 3*: Not chosen as of 2013
- *Region 4*: University of Tennessee, Southeastern Transportation Center (Safety)
- *Region 5*: University of Minnesota, Center for Roadway Safety Solutions (Safety)
- *Region 6*: University of Oklahoma, Southern Plains Regional Transportation Center (State of Good Repair)

- *Region 7*: Iowa State University, Midwest Transportation Center (State of Good Repair)
- *Region 8*: North Dakota State University, Mountain-Plains Consortium (State of Good Repair)
- *Region 9*: University of California, Berkeley, University of California Center on Economic Competitiveness in Transportation (Economic Competitiveness)
- *Region 10*: Not chosen as of 2013

Tier 1 UTCs

- *Economic Competitiveness*: University at Buffalo, State University of New York; Transportation Informatics University Transportation Center; University of Arkansas, Maritime Transportation Research and Education Center; University of Illinois, Urbana-Champaign, National University Rail Center; University of Southern California, Metropolitan Transportation University Transportation Center; University of Texas, Austin, Data-Supported Transportation Operations and Planning Center
- *Environmental Sustainability*: Maine Maritime Academy, Marine Engine Testing and Emission Laboratory; University of Alaska, Fairbanks, Center for Environmentally Sustainable Transportation in Cold Climates; University of Central Florida, Electric Vehicle Transportation Center
- *Livable Communities*: Montana State University, Small Urban and Rural Livability Center; University of South Florida, National Center for Transit Research; Western Michigan University, Transportation Research Center for Livable Communities
- *Safety*: Florida State University, Center for Safe and Accessible Transportation for an Aging Population; Ohio State University, Crash-Imminent Safety University Transportation Center; University of Iowa, Safety Research Using Simulation Center; University of Michigan, Center for Advancing Transportation Leadership and Safety; University of Nevada, Reno, Institute for Safety and Operation

of Large-Area Rural-Urban Intermodal Systems; University of Texas, Pan American, University Transportation Center for Railway Safety

- State of Good Repair: Florida International University, Accelerated Bridge Construction University Transportation Center; Michigan State University, University Transportation Center for Highway Pavement Preservation; Missouri University of Science and Technology, University Transportation Center for Research on Concrete Applications for Sustainable Transportation

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See Also: Moving Ahead for Progress in the 21st Century; U.S. Department of Transportation.

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Unmanned Aircraft

As the use of unmanned aircraft systems (UAS) becomes a component of daily life, one must consider what issues or concerns may arise from their presence in both existing infrastructure and society. The benefits of UAS have been widely recognized by the civilian sector through military testing and application; however, military systems are primarily used for tasks not reliant upon or regulated by the Federal Aviation Administration (FAA). When UAS are introduced into the civilian sector, a new list of paradigms become apparent that could affect regulation on issues such as see-and-avoid, privacy, FAA regulation, and pilot licensure.

In 2010, the National Aeronautics and Space Administration (NASA) finalized a report on UAS's integration into the National Airspace System (NAS) and added communications, UAS vehicle

interface design, certification, and interoperability to the growing list of concerns. The impacts of these issues weigh heavily on the individual manufacturers of UAS systems, policy makers, and the pilots and operators who plan on conducting commercial activities with them.

Throughout aviation's history, there have been many changes and radical advancements in technology that have had a great effect on the efficiency of the system. In the 1950s, jet aircraft started to infiltrate the skies, allowing people to travel greater distances at greater speeds and higher altitudes. It is important to consider that this change in the system was not simple and brought about a new list of concerns, some of which had never been encountered.

This complex change in the system could be referred to as a paradigm shift, where the system had to grow and become malleable in order to support the required changes in infrastructure. The integration of UAS into the NAS and into society is no different. It is another paradigm shift for aviation, where a new level of stability will be achieved through maturation of policy, regulation, and perceived trust in future technologies.

The path to complete success has yet to be drawn, but aviation experts and policy makers are working in a synergistic effort to understand how each issue may be addressed in order to allow advancement. See-and-avoid, automation, privacy, and regulation are primary issues affecting the implementation of UAS and must be assessed to provide the framework for UAS integration.

See-and-Avoid

In the 1950s, with jet airliners making the world a smaller place, airway designers and airspace integration experts had to derive methods to keep aircraft from having collisions. The existing infrastructure of the NAS was in need of restructuring. Since that period in history, the need for restructuring has become apparent again.

The FAA is striving for a partial integration of UAS into the NAS by 2015. This effort would include smaller aircraft operating from the surface to 400 feet weighing less than 55 pounds, along with more substantial aircraft that may operate up to 65,000 feet and travel in excess of 400 miles per hour. The issue that arises is an increased amount of air traffic in a finite area, in an airspace already crowded by commercial and general aviation aircraft.



A U.S. Air Force F-16 flies alongside an MQM-107E Streaker target drone during exercises over Tyndall Air Force Base in Florida. Military drones such as the MQ-1 Predator are able to operate up to altitudes of 18,000 feet, and some unmanned aircraft systems (UAS) may operate at up to 65,000 feet at speeds of over 400 miles per hour. The potential for incursions into the airspace of other aircraft has caused the Federal Aviation Administration to work toward partially integrating UAS into the National Airspace System by 2015.

The FAA, in an effort to advance and promote cutting-edge technology, has implied that modifications to the current system through the development and implementation of NextGen technologies will provide a viable solution to infrastructure-related concerns, effectively ensuring growth and development of the overall industry.

The current NAS is comprised of a system of Very High Frequency Omni-Directional Ranges (VOR) airways along with antiquated radar systems. The term *see-and-avoid* has become a common phrase in aviation to express the concerns of aircraft incursions both on the ground and in the air. This concern becomes increasingly prevalent with the integration of more aircraft into the existing infrastructure.

The application of Automatic Dependent Surveillance-Broadcast (ADS-B) technologies has been increasing and will likely replace systems already highly utilized by manned aircraft, such as Traffic collision avoidance systems (TCAS) that will not be approved for UAS see-and-avoid applications. The FAA has proposed a ruling that would make ADS-B

technologies a required component in all aircraft operating within the National Airspace System by 2020, ensuring more efficiency in aircraft separation for safety.

Regulations for the operation of manned aircraft depend on a number of factors regulated under Part 91 of the Code of Federal Regulations: Federal Aviation Regulations. In-flight visibility and weather conditions are important in considering whether the aircraft is under positive control by an air traffic agency or whether it is flying freely through the NAS. Both private and commercial flight operations can be considered to operate in two different regimes, which are referred to as Visual Flight Rules (VFR) and Instrument Flight Rules (IFR).

Aircraft operating under VFR are less restricted because environmental conditions do not constitute a loss of visual separation from other aircraft. Pilots operating in VFR conditions are responsible for maintaining visual separation from other aircraft.

IFR are different in that the pilot may not be able to see other aircraft because of environmental conditions. For instance, if the in-flight visibility is

reduced below one mile in uncontrolled airspace, a pilot may not have a clear view of nearby traffic. In the case of an aircraft operating in IFR conditions, air traffic control (ATC) would provide separation services through the use of radar systems.

For UAS, pilots control the aircraft from a ground control station (GCS), which is a ground-based flight deck. These systems may be as simple as a standard controller, such as a game-style joystick, or as complex as an integrated unit in a mobile command center. UAS may be controlled by a pilot or autonomously by a computer.

The type of system used to control a UAS from the ground is dependent on the type of aircraft, which may dictate the type of flights that may be conducted. For instance, smaller systems operating in the general vicinity of the user within line-of-sight (LOS) would typically be restricted to VFR daytime conditions because of aircraft and pilot limitations. Other systems, such as the MQ-1 Predator military drone, are able to operate beyond-line-of-sight (BLOS) up to altitudes of 18,000 feet, because the pilot receives telemetry data downloaded from the aircraft even though the UAS is out of sight. In this case, see-and-avoid becomes a primary concern for other aircraft operating within the same airspace.

With further integration of unmanned aircraft into the system, see-and-avoid protocols will be tested to their maximum limits, requiring research and evaluation to maintain the overall integrity of the NAS.

Automation

Automation refers to what level of control the pilot has over an aircraft. Sheridan's scale of degrees of automation defines that level of control by number, with 1 being the lowest and 10 being the highest. The measure is calculated by the presence or omission of human-in-the-loop (HITL) interaction. As the human progressively evolves out of the system, the level of automation becomes higher.

Levels of automation are important determinants for the complexity of the system and affect how policies and regulations are drawn. For instance, an aircraft classified as a level 1 by Sheridan's scale would require no computer interaction with the pilot, whereas an autonomy level of 10 would completely remove the human operator from the system. Each aircraft and pilot would require a different set of

operational guidelines and regulations in order to assure the safety of the flight crew, other aircraft operating in or around the craft in the NAS, and the general public.

The operation of UAS at a distance unobservable by the operator is referred to as beyond-line-of-sight (BLOS). This is accomplished through a satellite uplink that communicates between the aircraft and the ground control station (GCS). In this case, it may be assumed that the aircraft has a high level of autonomy where the operational aspects of the aircraft would be heavily reliant on the use of a computer.

For BLOS applications, the complexity of the system increases, causing concerns about such an occurrence as a loss in communication between the aircraft and the GCS. Manufacturers have worked to mitigate this issue by providing aircraft with a secondary flight plan in the case of lost communication with the GCS. For instance, the aircraft may "loiter" in a holding pattern to re-establish a connection or return to a predesignated point along its flight plan.

Privacy

To a society that relies on interpretation of the Constitution, Fourth Amendment protections of privacy are of the utmost concern. Many opponents of UAS imply that aircraft will be used for aerial surveillance that may infringe on an individual's rights as a U.S. citizen. This particular area of concern has become an issue in the operation of manned aircraft, too.

Lawmakers in many states have worked to pass legislation that would create significant boundaries for UAS operators. For instance, in April 2013, Idaho Governor Butch Otter signed into law the first bill in the nation protecting individuals from unfettered surveillance by UAS. Virginia also enacted a bill that would impose a two-year moratorium on law-enforcement drone use, except in emergencies. Other states, including Tennessee, are requiring law enforcement to obtain a warrant in order to use UAS.

Legislative outcomes carry a significant level of complexity. In many cases, the determination of whether the aircraft is categorized as UAS depends on its intent for use. Powered model aircraft have been in existence since the beginning of the 20th century and have had mild rules and regulations for operation.

UAS, on the other hand, with the capability of carrying payloads for surveillance, mapping, and other purposes, have been included in a different category of operation. For instance, a model aircraft may be flown recreationally with sensor equipment representative of UAS; however, if being used privately for the sole purpose of recreation, it would not be considered a UAS. The guidelines and protocols for operation can be somewhat ambiguous in nature because of the uncertainty of where legislative and government powers will take regulation in the near future.

Regulation

The FAA is the primary source for policy and regulation management for the operation of both manned and unmanned aircraft. Federal Aviation Regulations provide a framework for the operation of aircraft, regulating the certification of pilots, aircraft, and operational rules, along with a gamut of other regulations required for aircraft to operate safely.

The FAA consistently evaluates regulations and changes them periodically to represent any technologies or situations that may require the allowance of a new system or technique with regard to aviation applications. In the case of UAS, regulations require a new system with a list of similarities to manned aircraft.

In order to implement regulatory changes for UAS, the FAA must go through an outlined list of procedures and produce an amendment or new section to the existing Federal Aviation Regulations, referred to as a Special Federal Aviation Regulation.

Special Federal Aviation Regulation 107 was designed to enable small UAS to operate safely in limited portions of the NAS with a primary temporal focus of accomplishing this in the shortest rule-making time frame.

Small aircraft would be those operating in day-time VFR conditions, weighing less than 55 pounds and being flown directly by a pilot. Looking forward in legislation, this will provide the testing ground to implement rules for larger aircraft. The majority of manufacturers are developing aircraft that fit into this category and will operate below 400 feet, providing the foundation for finding operational issues and concerns that will directly translate into larger UAS regulations.

As the operation of the UAS industry matures and more civilian aircraft are developed and tested, the proper regulation will be finely tuned and evolve to provide the greatest level of safety and efficiency to the stakeholders responsible for the operation of UAS.

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See Also: Aeronautics; Air Traffic Control; Aircraft Design; Airplane Navigation Systems; Federal Aviation Administration; National Airspace System.

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Unsignalized Intersections

According to the generally accepted traffic safety definition, an unsignalized intersection is simply an intersection without a traffic light, not only full stop lights (with red, green, and yellow signals), but also blinking yellow and red lights. This definition does not generally include traffic signs.

While unsignalized intersections are present in both urban and rural areas, they are more likely in rural or suburban areas. The most common type of unsignalized intersection is made up of a major road meeting with a minor road; the minor road may have a stop or yield sign, but this is not always the case. In terms of public safety, intersections,

especially unsignalized intersections, are of major concern. All types of intersections have dramatically higher accident rates than the rest of the highway system. Furthermore, unsignalized intersections pose the same risks as signalized intersections with a higher risk of fatalities.

Dangers

While they may seem quite ubiquitous to the average driver, intersections actually make up a very small part of the total American highway system. Despite this fact, accidents are dramatically more likely to occur at intersections than at other locations along roadways.

According to a study produced by the National Cooperative Highway Research Program in 2003, more than 50 percent of all crashes in urban areas occur at intersections, and more than 30 percent of accidents in rural areas occur at intersections. Furthermore, the chance of collision not only increases at unsignalized intersections but those collisions also become more dangerous. Nearly 35 percent of crashes at unsignalized intersections involve injuries and 9 percent of intersection accidents involve fatalities. In comparison, as few as 6.5 percent of fatalities occur at signalized intersections.

It may not be surprising that unsignalized intersections are far more common in rural areas than in urban areas. Also to be expected, as population and development increases, traffic at unsignalized intersections sees a corresponding increase. If this increase in traffic at the unsignalized intersection hits a critical point, and that occurrence comes to the attention of transportation officials, a stop light may be installed. Thus, while there are currently many more unsignalized intersections in the United States than signalized intersections, signals are becoming more common.

Improvements

Traffic safety officials have two basic methods through which to reduce the risk of collision. Either the situation can be improved for safe drivers or the behavior of risky drivers can be addressed. The former is far easier to address, but there have been efforts to engage the latter, as well. In order to understand efforts to reduce the risk of collision at unsignalized intersections, one must understand all the objectives improving these intersections,

then seek to understand the strategies utilized in improving those intersections.

The reasons to improve unsignalized intersections are many, and many of these reasons may not seem obvious to laypeople. This article does not provide a complete list of reasons to improve an intersection, but it does provide some of the most common and important reasons to improve intersections.

First and foremost, traffic engineers seek to reduce the frequency and severity of incidents by changing the geometric design of the intersection (for example, changes to improve driver sight distance). Traffic engineers may also seek to not only improve the availability of gaps in traffic but also to assist drivers in judging gap sizes between cars at the intersection.

Efforts may be made to improve driver awareness of an upcoming intersection as viewed from the road prior to the approach. Efforts can also be made to improve driver compliance with traffic laws at the intersection through such traffic control devices as traffic cameras. Traffic engineers may also seek to reduce operating speeds on specific intersection approaches; this can be accomplished by either lowering the legal speed limit or by making alterations to the driving environment that coerce drivers to reduce the speed of their vehicles. Finally, efforts may be made to guide motorists more effectively through complex intersections.

There are a great variety of strategies aimed at improving the safety of unsignalized intersections; this entry discusses only a few. These strategies can be divided into three classifications: proven, tried, and experimental.

Proven strategies are those that have been used in one or more locations. Additionally, strategies are proven through scientific evaluations performed by traffic analysts. After evaluation, the strategy can then be used with a good degree of confidence. Examples of proven strategies include installing left-turn lanes, providing right-turn lanes at intersections, realigning intersection approaches to reduce or eliminate intersection skew, and improving visibility for drivers by improving lighting.

Strategies that have been classified as "tried" have been implemented at actual intersections but have not been subject to scientific evaluations. Thus, these strategies may be generally accepted as improving the safety of the intersection, but they lack empirical proof. Tried strategies include

implementing driveway turn restrictions, creating longer left-hand turn lanes, providing bypass lanes on shoulders at T-intersections, restricting or eliminating the turning maneuvers available to drivers, and providing channels through median openings.

Experimental strategies are those that have been suggested and seriously considered for implementation but have yet to be tested in an experimental setting. An example of an experimental strategy is providing an automated real-time system to inform drivers of available gaps for making turning and crossing maneuvers.

Issues With Signalizing

Efforts to install signals at currently unsignalized intersections are not without controversy. There are financial costs associated with installing and maintaining signalized intersections; this could be an issue for proponents of regional and local austerity.

It should also be noted that installing signals is not a universal solution for improving the safety of unsignalized intersections; signals must be installed strategically and with purpose. If improperly installed, signals may disrupt the flow of traffic. Such disruptions can lead to delays and even dramatically increase the risk of rear-end collisions.

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See Also: Automated Traffic Enforcement; Automobile Accident Avoidance Systems; Automobile Accidents and Prevention; Intersections; Road Surface Marking and Markers; Roundabouts and Traffic Circles; Traffic Safety and Risk Assessment.

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Upstream Signalized Crossovers

An upstream signalized crossover (USC) is a type of intersection designed as an unconventional way to handle left turns at intersections in order to improve performance. It was first proposed by Vener Tabernero in 2004, as his master's of applied science thesis in civil engineering at the University of British Columbia (UBC). Tabernero went on to become a civil engineer and has continued to publish on the topic of USCs as does his thesis adviser at UBC, Tarek Sayed.

Left turns are a significant factor in traffic flow, gridlock, and safety issues at conventional intersections, because a left turn takes the vehicle across the path of traffic perpendicular to the street onto which the vehicle is turning, whereas right turns require, at the most, joining the flow of traffic without crossing it. Further, vehicles in opposite-headed lanes turning left may come into conflict when each one turns, whereas the same pair turning right would not approach each other.

Left turns also impose a limit on the intersection's capacity and performance. Quite often at conventional intersections with traffic signals, the left-turning vehicles are the controlling element of the intersection's operation, with their presence and volume impacting the sequence and type of the traffic signal phases.

The various proposed solutions to the left-turn issue have been either measures to modify existing intersections, such as optimized signal timing or turn lanes, or designing unconventional intersections. Tabernero's thesis work introduced the USC as such a solution.

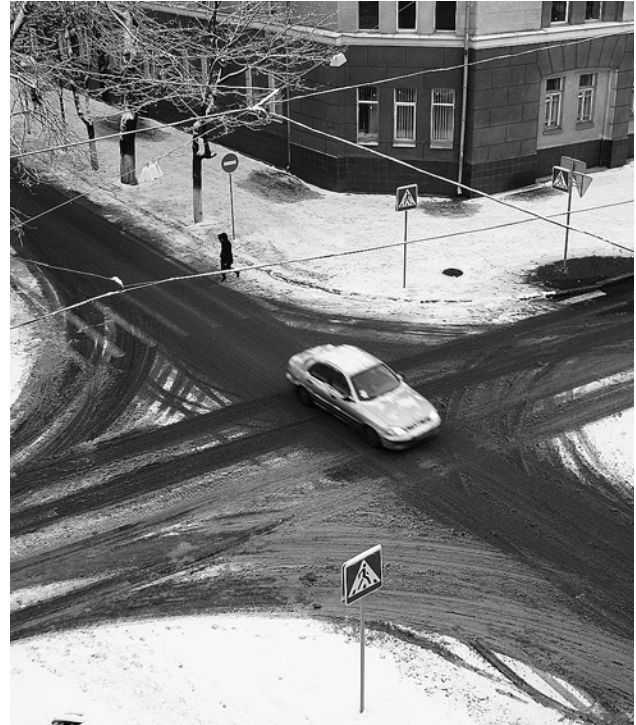
The USC is a four-legged intersection in which left-turn opposing conflicts are avoided by the left and through traffic of each approach being crossed to the left side of the road. Traffic upstream of the intersection crisscrosses, requiring four secondary signalized intersections at those upstream points, hence the name of the intersection.

Right-turn traffic remains on the right side of the road, but left-turn and through traffic crosses the median to the left side of the road, arriving upstream of the intersection. This is done in all four directions, creating the criss-cross effect and allowing left turns to be made without coming into conflict with one another.

In simulations, the USC cuts delay time and the number of crossing conflicts in half, and is able to accommodate 15 percent more traffic than a conventional intersection before failing (that is, becoming congested). As predicted, the USC is less sensitive to the volume of traffic in the left-turn lane, whereas in a conventional intersection, increased volume in left-turn lanes brings about congestion and increases delays at a much faster rate than overall volume increases.

USC intersections shift traffic to the side so that left turns are functionally similar to right turns at conventional intersections, insofar as they do not result in opposing vehicle conflicts. The redirection requires the signaling indicated in the name, and with proper coordination of the signals, the intersection can be negotiated with significantly fewer delays. The secondary intersections handle left-turn and through traffic crossing over from one direction, as well as departing traffic in the other direction, which consists of through vehicles and left-turners from the cross street. Right-turn traffic simply turns right, via a right-turn bypass, and is then merged back into traffic upstream of the secondary intersection.

The primary intersection can operate on as few as two signal phases because the secondary intersections mean there is no need for a “green left arrow” phase in which left turns are protected. The secondary intersections also operate on a two-phase cycle because they do not permit turns, and so only need to regulate approaching and departing traffic. An optimized USC coordinates the two sets of signals so that a continuous green band carries from the secondary intersection on one side of the primary intersection to the secondary intersection



An unsignalized intersection in Kharkiv City in the Ukraine in 2011. A 2003 study found that almost 35 percent of crashes at unsignalized intersections lead to injuries, while 9 percent involve fatalities. In comparison, only about 6.5 percent of fatalities occur at signalized intersections.

on the other side, with the green bands for the cross street offset to minimize the primary intersection's cycle length.

The major problem USC presents is the potential confusion of drivers at both the primary and secondary intersections, and the chance of the path through the secondary intersection inducing feelings of drivers being on the wrong side of the road. This danger seems heightened for drivers new to the USC, which might make it inappropriate for use in intersections trafficked by a large number of nonlocal drivers, such as in tourist areas or near airports or car rental agencies.

Driver confusion could occur not only when approaching the unfamiliar-looking intersection or when entering the secondary intersection, but when making a left turn, when muscle memory and habit may cause the driver to instinctively begin to turn left around the central median. This could possibly be mitigated by extending the central median, and certainly clear signage would be necessary.

Another disadvantage of the USC is that although each intersection involves fewer signal phases, the fact that there are two intersections instead of one means there are more stops, which introduces the possibility that the frequency of rear-end collisions would be increased. This is a trade-off experienced by most signaled intersections, where the traffic flow control introduced by the traffic signal reduces collisions overall but increases rear-end collisions.

It is likely that the increase in rear-end collisions as a result of having two stops is not as severe as the increase between a signaled and an unsignaled intersection, but the actual increase is unknown. Driver confusion can lead to hesitation, which can increase the frequency of rear-end collisions when hesitating drivers slow down unexpectedly.

At the secondary intersections, there may be an increased risk of crossing collisions. The angle at which cars exit the secondary intersection creates a longer path to clear the cross section than at a conventional intersection, and as a general traffic-flow rule, longer crossing distances increase the odds of the final car to cross violating a red light, which is a major factor in crossing collisions.

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See Also: Intersections; Road Surface Marking and Markers; Traffic Engineering; Traffic Flow.

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Urban Mass Transit Act of 1964

The Urban Mass Transit Act of 1964, signed into law by President Lyndon Johnson and based on the transportation policies of his predecessor John F. Kennedy, created the Urban Mass Transportation Administration (UMTA), which has since become the Federal Transit Administration (FTA). The act provided matching funds for cities or states to fund public or private rail projects.

The UMTA and later FTA grew beyond the scope of the original act, with funding reauthorized by later transportation bills, and provided financial and technical support for projects ranging from bus routes to light and commuter rail, subway systems, monorails, personal rapid transit systems, passenger ferries, streetcars, and people movers.

While the original bill authorized only \$375 million in funding, for instance, \$12 billion was authorized by the Urban Mass Transportation Act of 1970, and the National Mass Transportation Assistance Act permitted those funds to be used for operating costs as well as construction costs, since the issue preventing the development of many local transit systems was the impact they would have on state and local taxes. Today most of the FTA's annual budget is spent on subsidies to state and local governments.

The legislation was enacted because of the importance the government placed on ensuring the quality of mass transit and access to it in America's cities. Both Kennedy and Johnson were deeply invested in improving the living conditions of the American people, which meant addressing social and economic inequities, whether in the form of Johnson's War on Poverty or in guiding transportation development through federal policy and funding.

The three pieces of legislation together defined important aspects of federal transit policy. For instance, while the 50:50 matching funds for public transit systems was criticized by opponents at the time (and since, when reauthorization bills come up) for increasing the size and spending of the federal government unreasonably, they are noticeably less than the 80:20 matching funds provided for highway construction. This may represent in part an area of uncertainty, or maybe compromise, in policy thinking on transportation: while highways, forming the nation's interstate roadway, are a matter of clear federal interest, it is less obvious that a local subway system is a federal responsibility.

Further, because funds were initially and more substantially made available for rail projects, that dictated the choices local and state agencies made. At a time when transportation research was toying with numerous projects from moving walkways to personal rapid transit systems, rail systems ended up the most practical to adopt, from a funding perspective, regardless of their relative merits. Bus services declined, and considerably less funding was available for pedestrian, bicycle, car share, or carpool projects.

Nevertheless, the legislation was considered a good sign for the rejuvenation of America's cities, which had begun with 1961's Housing Act (which included a transportation research component in its funding targets) and continued with Johnson's Great Society programs. The era's concern for the holistic health of American cities in the face of gentrification and the onset of suburban sprawl is visible even in the children's television show *Sesame Street*, which first aired in 1969 and takes place in a diverse urban neighborhood that is noticeably pedestrian-oriented and self-sufficient.

It is common today to conflate mass transit and public transit, and the 1960s and 1970s transportation bills may be partly responsible for this, as most mass transit is now at least publicly subsidized. Public agencies were able to take over private transit companies with matching funds, though in some cases throughout the country, the mass transit system is operated by a private company that contracts with the public agency responsible for it. Mass transit had largely been pioneered by private companies that obtained the right to use public rights-of-way from local governments. The modern New York City subway,

for instance, includes rail lines originally built for the private elevated train, and the private elevated train and streetcar networks serving all five boroughs exceeded the public subway system in coverage. On the other hand, relocating the transit system to primarily underground created an overall public good—freeing up vast above-ground real estate that would otherwise be occupied by transit lines—in a way that government is uniquely suited and uniquely motivated to do.

Conclusion

While opponents expanding 21st-century publicly funded mass transportation projects sometimes construct arguments for the superiority of private mass transit systems and blame the expansion of public transit for private transit's virtual death, there is another way of looking at it. Public funding for mass transit came at a time when the automobile was finally becoming the default mode of transportation for Americans—a time when driver's licenses were being issued to the first generation to take driving for granted, right on the cusp of the spread of suburban sprawl that depended on most of its residents being two-car households. Rather than killing private transit, legislation like the Urban Mass Transit Act may have saved mass transit at a time when the popularity of the automobile was threatening to bleed it dry.

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See Also: Federal Aid Highway Program; Federal Transit Administration; Federal Transportation Policy; Fiscal Politics; Transit Planning, International; Transportation Policies, North American.

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Urban Mass Transportation Assistance Act of 1970

Before 1970, federal transportation law helped subsidize highway growth in the suburbs, but during the 1970s dozens of new mass transit systems were constructed in predominantly urban areas. Many people who utilized this mode of transport did so in order to get to and from work, with many riders commuting from the suburbs to the central business district. For such a commute, in 1970, a single-ride transit fare from Queens to Manhattan in New York City cost 30 cents. The impact of the Urban Mass Transit Act of 1970 is examined in terms of the accommodation of people with disabilities, protecting the environment, the role of government, and long-standing financing.

Public Law 91-453 was a landmark in federal financing for mass transit because it provided the first long-term commitment of federal funds. Its enabling legislation was titled the Urban Mass Transportation Assistance Act of 1970, which was approved by Congress in October of 1970.

Previously, federal funds were short term; therefore, it was difficult to plan and implement mass transit projects over several years because of the uncertainty of future financing. Because monies came out of general revenues, not special taxes, it ensured long-term financing.

In section 9 of the law, Congress authorized \$10 billion of funds to be distributed over a 12-year period with \$3.1 billion available beginning in fiscal year 1971. Recipients had to match every two federal dollars with one dollar, and no more than 12.5 percent of the total budget could go to any single state. In addition, this legislation included grants to city planning agencies to incorporate comprehensive planning principles at all levels of government and administration.

Transit costs included initial construction, continual operation, periodic maintenance, and everyday management. The law funded rights-of-way, station sites, and relocation payments for displaced private property owners. Furthermore, monies could be used for the extension of existing transit systems, modernization, new buses, and retrofitting the existing transit fleet for access by the elderly or people with disabilities.

Since millions of Americans experienced immobility problems while using these systems, the federal government responded to this issue in a new manner. Legislation was inserted into the act to remove obstacles for the elderly and people with disabilities.

Mario Biaggi was a freshman U.S. congressman from the Bronx, New York, who made a name for himself when he successfully modified the bill. The Biaggi Amendment, which was embedded in section 6, asserted the equal rights of disabled persons and mandated that transit authorities make “special efforts” to accommodate handicapped persons and the elderly.

Some historians claim that the push for equal accessibility was in part due to the large number of wounded veterans returning from combat during the Vietnam War. To end the segregation of people with disabilities and the elderly from able-bodied people through the use of customized vans with door-to-door service, the existing mass transit fleet needed to be retrofitted. Accommodations included new ramps and lifts on buses, lowered bell cords, specialized seats, and improved handrails and elevators at stations. All in all, the act approved 3.5 percent of the total funds to finance retrofitting and it enabled the governor of each state to distribute funds.

At this time, the government’s role in mass transit was part of President Richard Nixon’s new federalist approach of decision making, which shifted authority away from Washington, D.C., to state and local officials. The Nixon administration named John Volpe, who was the former governor of Massachusetts and a champion of mass transit, as the secretary of transportation.

In addition, this law included provisions that required public entities receiving federal funds to enter into agreements approved by the Department of Labor to ensure that the transit authority negotiated with labor unions in order to receive funds. Previous transit programs were often opposed by labor unions because they did not protect workers. Besides supporting laborers who worked on these billion-dollar projects, this legislation also provided for the protection of the environment.

The impact that mass transit had on the environment was significant. Under section 5, the legislation dealt specifically with provisions to safeguard the environment. For example, it mandated the creation of environmental impact statements on all projects as well as the disclosure of these published reports

to allow for citizen participation at public meetings. Moreover, it required the secretary of transportation to determine if there was an alternative plan based upon negative environmental impacts.

The act was friendly to the environment because mass transit is a more fuel-efficient and cost-effective way to travel compared to driving an automobile. These provisions should not come as a big surprise because six months before the legislation's approval, Americans celebrated the first Earth Day, which engaged 20 million citizens, some of whom persuaded politicians to pass eco-friendly laws. As a result, numerous regulations to improve environmental quality were passed during the 1970s.

Overall, the important contributions of the Urban Mass Transportation Act of 1970 were diverse and consisted of reduced pollution of the environment, increased handicapped accessibility, a longer-term commitment for federal funding, less time lost by commuters as automobile traffic jams eased, and better access to jobs for people without cars.

One quantitative study showed that transit ridership increased in the cities that obtained the most federal aid, although transit usage decreased in the communities receiving the least amount of assistance. Ever since 1970, America has witnessed the creation of dozens of new rail transit systems; however, bus service ridership continued to decrease. In the end, mass transit helped lessen the country's reliance on foreign nations in order to obtain oil for vehicular transportation.

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See Also: Buses; National Mass Transportation Assistance Legislation; Subway Systems; Transit Systems; Transportation and the Disadvantaged; Urban Mass Transit Act of 1964.

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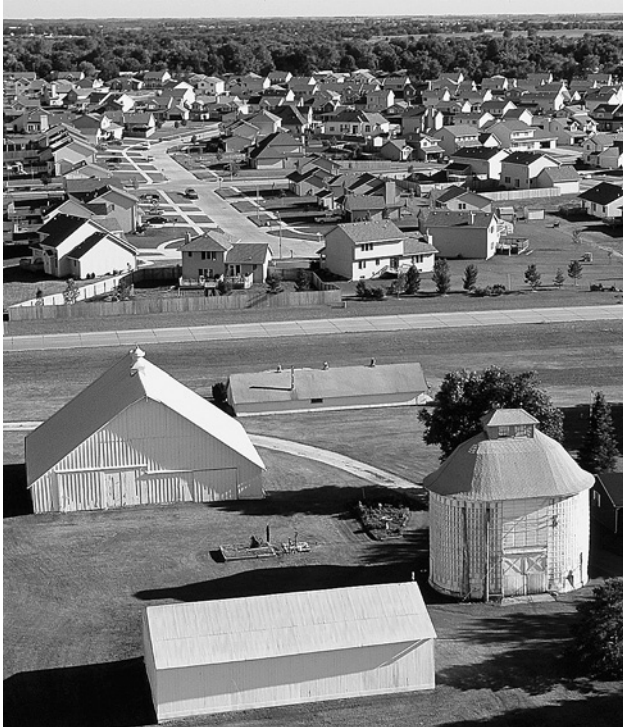
Urban Sprawl Versus Compact Development

The terms *urban sprawl* and *compact development* refer to opposite ways of using space to develop built environments. Urban sprawl refers to the way that cities expand even into rural areas, creating low-density communities taking up vast amounts of land. This also means that there is a relatively large amount of space between structures. Many see low-density development of land as wasteful, socially harmful, and, in the long run, more expensive.

The term *suburban sprawl* is sometimes used interchangeably with urban sprawl because it has often been suburbs that arose as a result of the spreading out. Urban sprawl is fueled by an automobile culture that enables people to drive long distances to get to their work spaces. This urban sprawl, fueled by the car, leads to congestion of the very roadways that brought people to less crowded spaces.

Compact development, on the other hand, conserves the use of land with a higher density of inhabitants, living in a variety of kinds of high-quality housing. Public transportation, an important partner of compact development, de-emphasizes the need for automobiles, thereby reducing the need for as much parking and reducing congestion of streets and roads.

The term *smart growth* has many of the same connotations as compact development. "New urbanism" is another movement that emphasizes, among other factors, compact development, neighborhoods independent of the automobile, and neighborhoods built with the pedestrian in mind. Urban sprawl is driven by a number of factors. The growing population of cities is one cause. An increase in demand for housing stock leads families and individuals to the market. Often land outside the city is cheaper and developers begin building subdivisions and individual homes not connected to subdivisions. As the



An area of new housing developments encroaching on a farm in Dallas County, Iowa, near the city of Des Moines in 2000. The loss of farmland like this through development can have ripple effects, such as increased dependency on corporate agriculture.

financial condition of families improves, they often want a home with more space and a bigger yard. They are driven outside the city by their desires.

There has also been a “back to nature” movement that causes some people to want to live closer to trees and wildlife. Some have experienced the negatives of the city and flee. Rising crime rates, poor urban school systems, and a decline in the quality of the urban housing stock are among the push factors that drive individuals from the city.

Impacts

The impacts of sprawl are numerous. These include a significant loss of land as property is developed in a non-dense fashion. Most buildings sit in an island of space surrounded by property that may have once been forest land, wildlife habitat, open space, or agriculturally productive fields. As sprawl has multiplied, the impact of the loss of undeveloped land has become significant.

The environment is negatively impacted through the loss of the land, whether it is loss of habitat or

loss of tree cover. Before suburban office parks, housing tracts and shopping malls, abundant farmland provided jobs for farmers and abundant harvests. Without these farms, the total population becomes more dependent upon corporate farms or imported food.

Urban sprawl can lead to drastic traffic congestion as roads into developments serve ever-greater numbers of commuters. This sprawl is also very expensive for local governments. As scattered developments are built, infrastructure must be extended. In a compact city, however, new housing is usually developed using the infrastructure components already in place or nearby, where they are simply extended short distances.

In locations impacted by sprawl, the infrastructure may need miles of expensive expansion. Local governments must also expand the availability of police, fire, and emergency medical protection. These local entities must also provide adequate school, library, and governmental service structures. Thus, urban sprawl may result in a great debt burden for local governments.

Urban sprawl can also lead to racial and economic segregation. As more affluent people, often white, move to the suburbs, they leave behind in city inner cores people with less economic opportunity, who are predominantly minorities.

Efforts to reduce urban sprawl and move to compact development have been multifaceted. One effort has emphasized redevelopment of inner cities. The basic infrastructure exists already and new housing and business development there prevents the need for additional urban sprawl. The effort can be summed up by the term *managed growth*. Uncontrolled growth leads naturally to urban sprawl and the rapid expansion of the use of land in a low-density manner.

Managed growth seeks to limit the unrestrained expansion of urban areas. It does not seek to end growth but to encourage compact development. Zoning regulations to protect agricultural and open land have been used. Eminent domain has been implemented with limited success. Financial incentives and disincentives have been used to encourage compact growth. A variety of legislative acts have also been enacted, with mixed results.

In New Orleans, after Hurricane Katrina, some parts of the city were dotted by landscapes with widely scattered surviving homes. Early in the

recovery phase, planners suggested making some of the most devastated areas green spaces while resources were freed to restore city services and utilities in less damaged areas of the city. In essence, planners were suggesting that the footprint of New Orleans be reduced and made more compact.

The loss of property tax revenue had already been significant because of the loss of homes and relocation of residents, and it was thought that the loss of tax revenue from any remaining homes that were habitable would be more than made up by the reduced services that would have to be provided. However, the opposition of homeowners, owners of the newly empty lots, and the politicians that represented them was so strong that the plan was abandoned.

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See Also: Automobile Culture; Environmental Impacts; Neotraditional Neighborhoods; Pedestrian-Friendly Design; Smart Growth; Transit-Oriented Development; Transportation Impacts on Land Use.

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Urban Trail Systems

Urban trail systems are connected open spaces located within an urban area and designed for the use of nonmotorized modes of transportation such as walking or cycling. The interest of urban planners in these systems has increased in the past few decades due to increased awareness of their benefits. The systems can enhance the livability of urban communities by improving accessibility to natural

environments, promoting healthful exercise, and facilitating human interaction, leading to important benefits in terms of public health. They also fulfill an important role in the sustainability of the urban environment.

The definition of "open space" in urban trail parlance is broad and can encompass different types of land cover and use, depending on the geographic, environmental, and social context of each city. Most urban trail systems include parks, gardens, reserves, lakes or rivers, and other spaces where vegetation is a predominant element. Riversides or sea fronts, canal towpaths, corridors along disused railway lines, and regenerated industrial areas may also be included in the system.

The main characteristics of these systems are the large number of component spaces and their connectivity, allowing uninterrupted access by nonmotorized modes, such as walking, cycling, or skating. Trail systems thus form a linear route linking different parts of a city or metropolitan area.

The concept is distinct from that of greenway because it presupposes access along the whole of the route, while greenways may include open space for the purpose of conservation and human access is partly restricted. Trail systems may also be connected with other car-free areas of the city, such as historical neighborhoods, shopping streets, shopping malls, or sport facilities. In some cases, public transit, such as electric buses or light railways, may also be allowed to use parts of the system.

Urban trail systems are a feature of many cities in developed countries. Cities in Europe have long developed trails along rivers and abandoned transportation infrastructure. In London towpaths along disused canals provide an extensive network used by walkers and cyclists. Trails may also be implemented in the space left by obsolete structures such as the Berlin Wall.

Many North American cities also have trail systems. For example, the system in Portland, Oregon, comprises a trail along the Willamette River and other streams and a network of parks and other open spaces, while in Toronto, Ontario (Canada), the lake waterfront is at the core of the project.

Most Japanese cities have also developed extensive trails along rivers. Throughout the world, urban trail systems are developing quickly following the popularity of programs promoting nonmotorized mobility, such as public rental bicycles.

One of the arguments for the implementation of this infrastructure is that it enhances urban livability. Trails can be used as corridors for walking and cycling as a means to access the workplace and urban facilities or to link nearby communities. The system can therefore facilitate human interaction and contribute to community cohesion.

People's sense of community may also increase because of the availability of places for social encounter and gathering, a role that local streets once filled but no longer fulfill effectively because of the noise, distraction, and dominance of motorized traffic.

Urban trails also increase accessibility to places with historical and cultural significance and provide spaces for recreation, cultural activities, and sport events, improving the experience of the city for both residents and visitors. The enjoyment of green and other natural areas also promotes environmental education and the feeling of closeness of humans and the natural world.

The benefits of trail systems in terms of public health are also important, because they provide opportunities for physical exercise. The benefits of walking, jogging, and cycling are widely recognized and include enhanced strength and flexibility and protection from cancer and heart diseases. These benefits are increasingly important given the current trends of aging populations and increasing obesity in most developed nations.

Living near and having the possibility of easily accessing open space and clean air also have benefits in terms of people's general physical health. Surveys indicate that outdoor recreation plays an important role in the mental health, well-being, and life satisfaction of urban citizens, allowing for relaxation and contemplation and thus providing relief from stress.

Urban trail systems offer important benefits as an alternative to daily commuting in cars, buses, and rail systems, which, research has found, is one of the most stressful activities in urban living. The trails may also provide an escape from the work environment during lunchtime breaks and from the home environment for residents in small and crowded apartments.

While urban trail systems are created for human activity, they also fulfill an important environmental and ecological role. The implementation of the systems is often done in conjunction with the revitalization of areas suffering from environmental



The Charles River Esplanade is a walking and biking path running alongside the Charles River in Boston, Massachusetts. Similar urban riverside trails can be found in London, England, and Portland, Oregon, among other cities.

degradation, such as rivers, lakes, and waterfronts, involving improvements in water quality, air quality, and a general clean up of natural areas. The inclusion of parks and natural reserves in the system, and the emphasis on their connectivity, also contributes to the conservation of wildlife and plants by helping preserve habitats and corridors for the natural movement of animals.

In addition, the presence of open space within the urban environment reduces the risk of flooding, while urban forests and other green areas have positive effects in the regulation of urban climate and air quality. The creation of facilities for the use of nonmotorized modes also contributes to a transportation modal shift, reducing traffic levels and the associated local environmental impacts, such as air pollution and noise, and regional and global effects such as the excess release of carbon dioxide (CO₂).

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See Also: Bikeways/Bike Lanes, Road Design Issues of; Complete Streets; Greenways; Health Issues; Livable Streets; Road Ecology; Urban Walkways.

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Urban Transportation Modeling System

The aggregate travel model, better known as the Urban Transportation Modeling System (UTMS) or the conventional four-step model (FSM), has been the dominant transportation model in the United States since the 1950s. One of the reasons it is called an aggregate model is because it uses aggregate socioeconomic (and land use) data from geographic areas, known as a traffic analysis zones (TAZs), rather than from individual household units

Development History

The aggregate travel model was first implemented on mainframe computers in the 1950s, serving as a tool for transportation planning analysis, such as identifying the most congested corridors, selecting the best freeway alternatives, and forecasting future traffic volumes and speeds. The highway orientation of the early aggregate travel model occurred naturally due to the massive wave of interstate freeway construction after the U.S. Congress enacted the Federal-Aid Highway Act of 1956. The initial model development of trip generation, distribution, and diversion led to the first comprehensive application of the FSM system

in the Chicago Area Transportation Study and Detroit Metropolitan Area Traffic Study around that time.

The 1960s brought federal legislation requiring "continuous, comprehensive, and cooperative" urban transportation planning, fully institutionalizing the FSM. Further legislation in the 1970s and the 1980s brought environmental concerns to planning and modeling, as well as the need for multimodal planning. After the enactment of the Clean Air Act Amendments of 1990, many states and metropolitan planning organizations (MPOs) have the added responsibility of demonstrating that metropolitan transportation plans conform to their State Implementation Plans, often through the reduction of mobile source emissions.

The Americans with Disabilities Act (1990), Intermodal Surface Transportation Efficiency Act (1991), Transportation Equity Act for the 21st Century (1998), and Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005) further mandated many changes in transportation modeling processes. New federal mandates, plus the completion of the interstate highway system, change in female labor participation, decentralized workplaces, urban sprawl, technological advancements, and other factors have created increasing demands on aggregate travel models, such as modeling nonmotorized transportation, truck movement, and smart growth, and integrating land uses and transportation.

The existing trip-based aggregate travel model is apparently not appropriate to meet these increasing demands. Recognizing this, the federal Travel Model Improvement Program (TMIP) was established in 1991. Much of the subsequent period has been directed at improving the state of the practice relative to the conventional FSM model while conducting new research and developing new methodologies such as disaggregate simulation of households, activity-based and tour-based modeling, integrated land use/transportation modeling, and many others.

Aggregate Travel Modeling Processes

Before transportation modeling starts, it is necessary to prepare a local land use forecast, also called small area forecasting. During this process, socioeconomic forecasts are made for the region as a whole. Such forecasts provide control totals for local land use analysis. Typically, the region is

first divided into TAZs (i.e., small areas). By trend, regression, or other type of technique, the population, employment, and other socioeconomic data are determined for each TAZ. The outputs from land use forecasting become the inputs for transportation modeling. The four steps of transportation modeling are trip generation, trip distribution, mode split, and trip assignment.

Trip generation is the first step in the traditional aggregate modeling process. The trip generation model estimates the number of person-trip ends (production and attraction) for each TAZ. These trip ends are calculated on a household, person, or employee basis and then aggregated to TAZ level.

The trip generation model consists of three steps: First, use the trip production model to estimate production trip ends by purpose by TAZ. Typical socioeconomic data elements for this model include income, automobile availability, household size, and number of workers. The important data sources are the census and household activity data. The trip production model typically uses a cross-classification model. Second, use the trip attraction model to estimate attraction trip ends by purpose by TAZ. For trip attractions, the most important data input is employment, which is broken down into basic employment, retail employment, and service employment. The important data sources are workplace and household surveys. The trip attraction model can use either a regression model or a cross-classification model. Third, balance trip productions and trip attractions to get final production and attraction trip end tables by purpose by TAZ. Since trip productions are believed to be more reliable, trip attractions are normally balanced to match trip productions for the entire modeling area, especially for home-based work trips.

Trip distribution is a way to determine where trips are coming from and going to. By matching productions with attractions, trip distribution will convert production and attraction trip ends tables from the trip generation step into trip table matrices by purpose. The most commonly used trip distribution models are the gravity model and growth factor model (also known as the Fratar model).

The gravity model takes the following equation form:

$$\text{Trips}_{ij} = \text{Productions}_i * (\text{Attractions}_j * \text{FF}_{ij} * K_{ij}) / (\sum \text{Attractions}_j * \text{FF}_{ij} * K_{ij})$$

Where:

FF_{ij} = the friction factor for TAZ_i and TAZ_j , which is inversely proportional to the travel impedance between these two TAZs; and

K_{ij} = the K-factor for TAZ_i and TAZ_j , which accounts for socioeconomic linkages not accounted for by the friction factor.

The growth factor model, or the Fratar model, is also an important trip distribution model. Many local cities use the growth factor model because they do not have the detailed friction factor and K-factor information, but they know the future growth rates and existing trip tables (T_{ij0}) in order to forecast future trip tables (T_{ij}).

There are three types of growth factor models. The first type is the uniform growth-factor model: the general growth rate g is known for each zonal pair, $T_{ij} = gT_{ij0}$. The second type is the singly constrained growth-factor model: the origin or destination specific growth factors g_i or g_j are available for each zonal pair, $T_{ij} = g_iT_{ij0}$ or $T_{ij} = g_jT_{ij0}$. The third type is the doubly constrained growth-factor model: two sets of independently determined growth factors g_i and g_j are available for each zonal pair, $T_{ij} = g_i g_j T_{ij0}$.

Mode split (also called mode choice) computes the proportion of trips between each zonal pair that uses a particular transportation mode. Mode split is determined by the relative cost/time for making the trip by each mode and the person/trip/land use characteristics, such as automobile availability, household income, household size, congestion, cost (parking, tolls, fares, out-of-pocket costs), and other factors. Some small cities do not use the mode split model because their trips are predominantly automobile trips, and the cost to develop a mode split model is rather high.

The mode split model has several techniques: analogy, elasticities, direct estimation of transit share, and the disaggregate mode split (DMS) model. Of all techniques, the DMS model is the most sophisticated and widely used; it is based on the discrete choice modeling concept developed by Nobel laureate Daniel McFadden in the 1970s and 1980s.

In the DMS model, the probability of selecting a mode is determined from utility equations, which use the concept of utility. A mode utility is

a combination of the mode's cost, travel time, and other factors that reflect the difficulty of using the mode. The higher the cost and time associated with the mode, the lower the mode's utility (i.e., the higher the mode's disutility), and the lower the probability that mode will be selected.

The most commonly used multinomial logit equation of DMS takes the following form:

$$P_i = e^{U_i} / \sum_{j=1}^n e^{U_j}$$

Where:

P_i = probability of mode i ;

U_i = utility of mode i ;

n = number of modes; and

e = natural log.

Trip assignment (also called route assignment) is the process of allocating a given set of trip interchanges to a specific highway or transit network. Highway assignment involves several algorithms. The most common are all-or-nothing assignment and equilibrium assignment.

All-or-nothing assignment assumes that the minimum impedance (travel time or generalized cost) route (path) for each origin and destination (O&D) pair is found. All flows (trip interchanges) between these O&D pairs are loaded on these routes. A given route receives all or nothing of a given O&D pair's flow, without any consideration of the capacity available on the route.

To perform all-or-nothing assignment, it is necessary to have a trip table assigned and to link information (free flow speed, time, and others) so that the uncongested impedance between the different O&D pairs can be computed. The following steps are performed: finding the shortest route between the TAZs; assigning all trips to links comprising the shortest route; continuing until trips between all TAZ pairs have been assigned.

Equilibrium assignment uses the concept of capacity restraint. Often Wardrop's principle of user equilibrium is applied when each driver (or group) chooses the shortest (travel time) path, subject to every other driver doing the same.

The concept of capacity restraint uses link flows (volumes), link capacities, and link speed to predict link impedance (travel time). The Bureau of Public Roads formula, used as a default in most model packages, shows this relationship:

$$T = T_0 [1 + 0.15(v/c)^4]$$

Where:

T = congested link travel time;

T_0 = original link (free flow) travel time;

v = assigned traffic volume; and

c = the link capacity.

This technique searches for a user equilibrium solution in which link flows and impedance are simultaneously solved. Under equilibrium conditions, traffic is assigned in congested networks so that no individual trip maker can reduce path impedance by switching routes. This assumes that trip makers know the traffic conditions on all routes.

In addition to highway assignment, transit assignment is also an important task for many agencies' transportation modeling processes, especially for large agencies. However, transit assignment is different and more complex than highway assignment because the network of transit services is different from that of vehicles. Links in this network include bus or rail service running between two stops or stations. Many of the public transit services share road links with private cars. These differences result in an assignment to a more complex network.

Unlike highway assignment, transit assignment involves the movement of passengers, not vehicles. Travel time includes both in-vehicle time and out-of-vehicle time, such as waiting at stops and walking to and from stops. Passengers also may transfer between two routes, and even drive part of the way to board a public transit service.

In a highway network, monetary cost is directly associated with fuel consumption, tolls, and parking. In transit services, the various fare structures determine the monetary cost associated with a trip. There is also transfer cost and parking if an auto is used to get to the transit station.

Model Estimation, Calibration, Validation, and Application

Model estimation includes statistical estimation procedures used to find the values of the model parameters (especially coefficients) that maximize the likelihood of fitting observed travel data, such as a household travel survey or onboard transit survey. Its focus is on correctly specifying the form of the model and determining the statistical significance of the variables.

Model calibration is used to adjust parameter values until predicted travel matches observed travel demand levels in the region. For example, calibration of the mode-specific constants in a mode choice model ensures that the estimated shares match the observed shares by mode (and often by mode of access).

To test the ability of the model to predict future behavior, model validation requires comparing the model predictions with information other than that used in estimating the model. This step is typically an iterative process linked to model calibration. It involves checking the model results against observed data and adjusting parameters until model results fall within an acceptable range of error.

The application of the model to future year conditions and policy options requires checking the reasonableness of projections, so there is a link between application and validation. The sensitivity of the models in response to system or policy changes is often the main issue in model application.

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See Also: Transit Planning, International; Transit Systems, Marketing Research and Public; Urban Transportation Planning Process.

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Urban Transportation Planning Process

Typically, the urban transportation planning process (UTPP) has seven steps: (1) inventory, (2) land use forecasting, (3) trip generation, (4) trip distribution, (5) modal choice, (6) network assignment, and (7) evaluation. The travel forecasting process constitutes elements 3 through 6 of the UTPP and is generally referred to as the "four-step" or "four-stage" modeling process.

Before World War II, transportation planning did not include any transport modeling/forecasting

elements. Thereafter, rapid suburbanization of U.S. cities and huge increases in federal government infrastructure spending created the need for more precise regional modeling of future travel patterns. Much of this early modeling work was developed in the Chicago Area Transportation Study (CATS), and these approaches have since been refined and improved upon considerably and incorporated into what is now a formal process—the UTPP.

Inventory

The inventory process is frequently the most time consuming and expensive component of the UTPP. It consists of the development of a database for evaluating existing travel demand and the performance of the existing transportation system. It is also the basis upon which future travel demand and transportation system requirements are estimated.

Essentially, the inventory process involves acquiring information about existing land uses, their types and distribution. It also involves surveying the population to obtain information about socioeconomic characteristics and people's travel habits, including the number of trips they take, where trips originate and terminate, and the extent to which people use various transportation facilities. Finally, an inventory of the existing transportation system is undertaken so that the capacity of the system and the characteristics of the level of service can be established.

Normally, transportation studies use some sort of areal unit system (e.g., census tract, traffic analysis zone [TAZ]) for compiling data. The exact configuration of this system is decided on at this stage and can significantly affect later analysis. During the inventory, it is also common to develop a set of networks in travel modeling software to represent the major roads and all transit lines.

Land Use Forecasting

The core objective of this element of the process is to forecast the configuration of the future urban system that any new transportation system is set to serve. This involves estimating the intensities and spatial distribution of future population, employment, and economic and social/leisure activity and how they are likely to influence future types and spatial distribution of land use.

Generally, these future trends are extrapolated using relevant existing national data (usually from

the census or other relevant sources) and land use and survey data gathered from the inventory stage. In some studies, land use models are used to forecast future intensity and distribution of land use activity over the planning horizon period (normally about 20 years). Data from the land use forecasting process is used as input for the travel estimation and forecasting process (steps 3–6).

Trip Generation

Trip generation is the first step of the four-step modeling process. It is concerned with predicting future levels of person or vehicular travel, normally for zonal units (e.g., TAZs) or a combination of such units by trip purpose and time of day. It involves estimating the total number of trips generated and attracted by each zonal unit as a function of socioeconomic, locational, and land use characteristics, which can be represented by variables that change with each zonal unit and with the time period under consideration.

Once the factors influencing travel demand have been identified for the base year, they are projected for a future year to provide estimates of travel demand. During trip generation, separate estimates are generated of trip activity at the home (e.g., home to work) and non-home end of a trip (e.g., work to recreation to shopping). The former are described as trip productions and the latter as trip attractions.

Two sets of factors are most important for influencing trip generation rates. The first is land use factors. Different land use categories (e.g., residential, commercial, retail) are associated with different trip generation rates. Similarly, land use intensity produces varying trip generation characteristics.

The second is household characteristics. These include family size, whereby higher mean values are associated with more daily trips; automobile ownership, whereby mean cars per household is associated with higher daily trip rates; type of dwelling unit; and occupational and income characteristics (higher-income households often have a greater ability to pay for movement). Beyond these, factors such as population demographics and the quality of the transport infrastructure, among other things, affect trip generation rates.

There are three general ways to forecast trip generation rates: (1) growth-factor modeling; (2) cross-classification, known as category analysis in Europe;

and (3) multiple linear regression. Growth factor modeling is rarely used in modern studies. Cross-classification aims to classify zonal household-level data into standardized subgroups (e.g., household size by automobile ownership) represented by average trip generation rates. Together with future estimates of number of households in subgroups, average trip generation rates are used to forecast trip productions and trip attractions.

Multiple linear regression is used where two or more factors are thought to affect overall trips being generated; it measures the separate influence of each factor in association with other factors in trip generation. The aim is to use base-year traffic, land use, and socioeconomic data to produce a regression equation representing the relative influence of each factor (independent variable) on the zonal trip rate (dependent variable) using the technique of least-squares fitting. This equation is then solved using future estimates of the independent variables (e.g., number of households, automobile ownership) to derive information about the number of trips generated by each zonal unit (the dependent variable) for the forecast period.

Trip Distribution

Trip distribution is conventionally the second step of the four-step modeling process, although it can be the third, depending on whether modal split is undertaken after trip generation. The objective is to distribute the forecast future total number of trips originating in each zone among all other possible destination zones. The process creates a matrix that relates origin and destination travel flows for the forecast year. For simplification, all trips are assumed to be separate, even though in reality significant trip chaining occurs. In addition, trip distribution is generally completed separately by trip purpose (e.g., home-based work, home-based other, non-home-based).

There are two sets of methods by which trips can be distributed: growth factors methods and synthetic methods. The growth factor approach was initially developed where the only information available was origin and destination total trip ends and a travel matrix of existing trip making. There are four main types of growth factor model: Uniform, Average, Fratar, and Detroit.

In all cases, the approach operates on the premise that future interzonal trip movements can be

predicted by a measure of anticipated future trip growth. The main difference between the models lies in the complexity with which growth factors are applied specifically in terms of interaction assumptions between origin and destination zones in the system. In existing practice, growth factor models are only used for short-term planning horizons.

For synthetic methods, the gravity model is widely used, but the opportunities model is also used. The gravity model states that travel (interaction) between two zones is directly proportional to the relative attraction of each zone (e.g., total population, employment) and inversely proportional to some representation of the separation between zones (e.g., distance, time). Synthetic models differ from growth factor models because they estimate future interzonal trips in the system without directly using the observed trip pattern. Modern-day models are more sophisticated than the simple gravity model and take a more realistic account of the effect of separation on interaction using a deterrence function, among other improvements.

For the opportunities methods, two approaches are generally used: the intervening opportunities model and the competing opportunities model. Both methods introduce probability theory as the theoretical basis for trip distribution. In addition, both models are conceptualized around two basic assumptions about human behavior. First, people minimize total travel time from their point of origin subject to every destination point having a stated probability of acceptance if considered. Second, the probability of a destination being accepted (if considered) is a constant, independent of the order in which destinations are considered. On this basis, the probability of trips terminating at each destination zone is estimated. Aside from the foregoing methods, entropy maximization, multiple linear regression, and linear programming methods can also be used to estimate future trip distribution.

Modal Choice

Modal choice (also known as modal split) is normally the third step of the four-step process but can sometimes be the second step. If the process occurs as the second step (i.e., prior to trip distribution) it is known as trip end modal choice; if it occurs as the third step it is referred to as trip interchange modal choice. The core objective of modal choice

modeling is to determine the assignment of person-trips to the various available modes of travel.

In the early days, this process was only concerned with splitting trips between automobiles and public transport modes, and this was a major weakness of the models; today, the majority of modal choice modeling involves the allocation of trips to all modes including walking and cycling, and indeed takes account of multimodal trips.

Numerous procedures exist for modal choice modeling, but all use the assumption that the proportion of trips carried via each mode (e.g., car, bus, cycling) is a function of the attractiveness of each mode relative to competing modes. The attractiveness of individual modes is based on a set of factors including the characteristics of the journey being made (length, purpose, time period of the journey) and the transportation system being used (travel time, monetary cost, comfort) as well as the characteristics of the individual making the journey (car ownership, income, socioeconomic status).

The exact methodological approach used for modal split varies depending on whether the process is completed as the second or third step. Trip end models allocate total person-trips to the various modes before trip distribution occurs. Thus, the extent to which they take account of the transport system characteristics is extremely limited. Most trip end models rely either on regression analysis or analytical models similar to the gravity model of trip distribution for deriving modal split (i.e., entropy maximization approaches) and are heavily reliant on individual characteristics of the user as the main determinant of modal choice.

On the other hand, trip interchange models are post-distribution models (i.e., they use as input the trip interchanges produced at the trip distribution step) and thus are more realistic in that they take account of the characteristics of the transport system. For this reason, trip interchange modeling is now widely used. Many existing city-regional models use a disaggregate modeling approach including multimodal split models (e.g., the N-way structure and hierarchical structure models) and discrete choice models, which are grounded in microeconomic theory.

Network/Route Assignment

The final step of the four-step process is network/route assignment. It is concerned with the

assignment of a given set of interzonal trip movements, by mode, to individual links on the rail, bus, and road networks. The basic assumption behind the operation of network assignment is that routes are chosen rationally by individuals to minimize travel time between origin and destination. More sophisticated models take account of other factors affecting route choice, including monetary cost and congestion, among others.

It is assumed that travel time on the route ultimately being used will be less than or equal to the travel time on other routes not being used for any given interzonal trip. The corollary here is that it is also assumed (somewhat unrealistically) that individuals are fully aware of all alternative routes that they might travel along when deciding on their choice of route. For input data, the network assignment process requires the proposed or existing transportation system as well as a matrix of future interzonal trip movements by mode, which is derived from the trip distribution and modal choice stages.

Standard procedures for assignment of future trips include all-or-nothing assignments, proportional assignments, and capacity-restrained assignments. Typically, all approaches use some variant of a minimum-path algorithm that assigns vehicles onto individual routes based on the minimum time path between origin and destination zones. All-or-nothing assignments involve loading all vehicles between a given origin and destination onto a single minimum-time path and assume zero congestion effects. Proportional assignment involves a percentage of vehicles being assigned at the outset, and then the minimum-time paths are computed after that portion of the assignment as the basis for the next percentage to be assigned. However, most modern urban transport authorities tend to use capacity-restrained assignment, in which vehicles are assigned to the shortest journey time routes for each origin–destination zonal pair.

Once a route has reached its carrying capacity, a new set of minimum time paths is derived using a set of adjusted travel times for accommodating the remaining trip movements. Thus, as vehicles on individual links slow down due to congestion, the model assigns some vehicles to other faster pathways until new assignments fail to provide travel time reductions in the system. Time of day must be represented during the assignment phase, and

normally the process is run for at least the peak and off-peak periods.

Evaluation

The final element of the UTPP has one basic objective: to decide whether or not a specific plan is worth implementing. This involves determining a range of consequences of plan implementation for users and nonusers of the transportation system and, in particular, for the environment, among other considerations. It also involves identifying at what point in time the plan will actually be worthwhile, specifically in terms of when net benefits can be realized (e.g., after 5, 10, or 15 years).

Perhaps the key difficulty with plan evaluation is that a weighting system must be devised to assign weights to each of the foreseeable consequences; this raises immediate problems with respect to how objective weights can be identified for consequences such as environmental effects that cannot be measured directly. Traditionally, monetary cost-benefit analysis has been the most widely used evaluation procedure. However, it has come under criticism for assuming that all costs and benefits can be reduced to monetary equivalents, a process that is wrought with difficulty.

Moreover, it tends to be overly concerned with user costs and benefits rather than incorporating corresponding information for nonusers. Beyond this approach, other evaluation methods such as least cost, least harm, maximum benefit, multicriteria analysis, and cost-effectiveness analysis can also be used for the process of plan evaluation.

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See Also: Mode Choice Models; Travel Demand Forecasting; Travel Model Calibration and Validation; Travel Modeling; Trip Distribution Models; Trip Generation Rates and Models; Urban Transportation Modeling System.

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Urban Walkways

In transportation literature, the term *walkway* is often synonymous with sidewalk. It can also refer to built paths more separated from roadways than sidewalks usually are. There is sometimes a buffer of space, often with plantings of trees or shrubs, that gives more isolation from roadways than do sidewalks. However, walkways and sidewalks are thought of together in terms of transportation policy and planning.

The Transportation Department of the U.S. government defines "urban" to be primarily towns and cities with more than 5,000 in population. The term *urban walkway* then would refer to sidewalks and other pedestrian-designated pathways in an urban area.

Sidewalks are usually built within the road or street rights-of-way. In some cities, there have been special types of walkways, built separately from sidewalks. In parts of London, an elevated walkway system was developed to help pedestrians avoid some of the congested ground-level foot and vehicle traffic. This system of walkways did not prove especially successful in part because of a lack of connectivity. These elevated walkways were often not populated with pedestrians and became somewhat scary to potential pedestrians because of their isolation. It had been hoped that an elevated walkway would lead to an additional level of commerce, but this never materialized.

Hong Kong has been successful in developing some elevated walkways separated from the dense traffic of the city. Some of these pedestrian walkways give pedestrians an avenue to avoid busy intersections. Some cities have developed underground walkways. There have also been efforts to

develop moving walkways in some urban areas to promote walking. These are often found in airports, and there may be a growing future for them on the streets of cities.

There is a growing interest in making urban areas more walkable. This refers to making it safe, convenient, efficient, and pleasant to walk to destinations within the city. The desire to promote walking is joined to the concept of making cities more bicycle friendly. Both of these are tied to the efforts to be more environmentally friendly, to reduce traffic congestion, and to promote good health through encouraging exercise.

Considerations for Planning

It is understood that for people to want to use urban walkways, there must be a presence of factors that make sure pedestrians will not be discouraged from their use. Planners and policy makers must consider a number of factors in preparation for the planning of these walkways.

The surface of the walkway must be adequate. This refers first to the width of the walkway. There is no single standard for how wide a walkway or sidewalk must be. The U.S. Americans with Disabilities Act encourages walkways to be at least six feet wide. The surface can be made of various materials, but it should promote comfort and safety. The slope of the walkway should be gradual so as not to present hills so steep that they impose barriers to use of the walkways.

Another important factor in promoting walkable cities is the presence of continuous walkways. If sidewalks are missing and people are forced into more interaction with motor traffic, then overall use of walkways will be lessened. Connectivity is important in designing pedestrian transit. If people are going to walk in the city, they must have the opportunity to easily get where they are going with walkways.

Sidewalks must be relatively free from barriers to walking. An excessive number of signposts, utility poles, and even street furniture can impede foot traffic. Though too much street furniture is to be avoided, there needs to be adequate seating so that people can rest, visit, and wait.

The density of the city needs to be such that pedestrians can accomplish many of their tasks without having to walk excessive distances. Land use should be mixed so that there are no urban

deserts in which only one type of establishment covers large blocks of territory. For instance, block after block of office buildings or warehouses without an intermixing of other forms of commerce would not promote walkability. Having shops, government offices, schools, recreational opportunities, and eating establishments scattered throughout the city promotes the use of walking and walkways.

Adequate separation of walkways from the roadways is essential. A proper buffer must be present. This buffer can be some combination of distance and barriers. Curbs are essential, and trees can give the pedestrian a sense of protection from traffic as well as provide a calming influence on the walker. Cities must also build into the transportation design ways to slow motor traffic to present less danger to the users of walkways.

The walkways should be designed in such a way that pedestrians will be able to use them in a variety of ways. For example, people should have room to stop and talk without impeding the flow of walkers. People need to be able to keep up their walking speed if they desire to do so.

Additional Factors to Consider

A lack of adequate walkways is a major barrier to a walkable city. A lack of separation of pedestrians from roadways is deadly. In cities where there may be more immigrants not familiar with traffic patterns and some unable to read English, there is an increased danger to pedestrians who do not have access to proper walkways.

Walkways, or sidewalks, should ideally be on both sides of the street. This is especially true for more heavily traveled roadways. Urban roadways should almost always have walkways on both sides.

Rural areas often do not have sidewalks along roadways. A footpath along the shoulder of the road is often all that is available. One way that walkways can be made more available is for local governments to require walkway construction to be a part of any new development. This can lead to a better level of connectivity even when the local governments may not be able to fully finance walkway projects.

Federal Support Increases

Federal funding for transportation projects has been crucial to the development of the U.S. national



A large elevated pedestrian walkway surrounds this roundabout in Shanghai, China, separating the pedestrian traffic entirely from vehicles on the roadway below. Experiments with elevated walkways in some other cities have not been successful, leading to isolated, unused facilities. However, in most cases, pedestrian activities have been found to increase when additional provisions are made for them.

highway system, and, more recently, attention has been directed to the promotion of bicycle and pedestrian transportation as well.

Each state is being required to have a coordinator responsible for looking out for the interests of pedestrians and bikers. The Intermodal Surface Transportation Efficiency Act (ISTEA), enacted in 1991, required states and metropolitan areas to develop comprehensive transportation plans, which were to include plans for bicycle and pedestrian transportation.

The Transportation Equity Act for the 21st Century (TEA-21), enacted in 1998, further defined the importance of including pedestrian and bicycle travel as transportation projects were designed. This act provided that, where feasible, as new

highway and road projects were designed, consideration should be given to providing safe routes for walkers and cyclists.

In 2005, Congress enacted the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This legislation accelerated the development of pedestrian urban walkways through several key provisions. One was the Safe Routes to School Programs, which provided \$612 million to be used by states and local governments, with an opportunity for private groups to receive funding as well, to help promote walking and biking to school in safe ways. Some funds were made available to provide new and improved walkways for the use of schoolchildren.

Several other provisions in SAFETEA-LU provided funding that could be used to promote pedestrian and bicycle transportation, and to ensure the safety of these modes of transportation. Walkways were improved as a result.

Congress passed the Moving Ahead for Progress in the 21st Century Act (MAP-21) in 2012. This act provided continued funding for alternative transportation initiatives, including programs that benefit pedestrians. It has been shown that pedestrian activities increase as additional provisions are made for walking.

With the increase in funding that has been made available in recent years for non-highway traffic, progressive state and local governments have been aggressive in expanding the availability of high-quality walkways and shared pathways. Shared pathways are walkways shared by pedestrians and, primarily, cyclists.

Educational funds have been provided, as well, and these have been used to educate the public about the benefits of increased pedestrian and bicycle use. The use of walkways is productive in its impact on the environment and in health benefits to those who take advantage of these urban walkways.

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See Also: Bicycle Commuting; Bicycling, Health and Recreational Aspects of; Bikeways/Bike Lanes, Road Design Issues of; Pedestrian Malls and Skywalks; Pedestrian Safety; Pedestrian-Friendly Design; Urban Trail Systems; Walking.

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U.S. Department of Transportation

Throughout much of American history, transportation policies were developed piecemeal, handled by a large number of federal, state, and local agencies. Thus, the transportation sector lacked a cohesive voice in developing national transportation policies. There were 17 unsuccessful attempts to create the U.S. Department of Transportation (USDOT) before plans for its creation were finally realized.

Pressure for creating a national transportation department began to mount in the 1960s in conjunction with widespread new developments in the field of transportation. In 1961, the staff of the Senate Committee on Commerce laid out a plan in the a report, making specific recommendations for the creation of the department.

Other recommendations followed, but it was not until 1966 that Congress passed the Department of Transportation Act, which ultimately cleared the way for the creation of the USDOT and established the secretary of transportation as a cabinet-level position. The stated purpose of the new department was to establish and coordinate policies governing the operation of "an efficient and economical national transportation system." Upon signing the act into law on October 15, 1966, President Lyndon B. Johnson declared that it was "the most important transportation legislation of our lifetime."

Finding a Voice

While serving as the head of the Federal Aviation Agency in the 1960s, aviation pioneer Najeef Halaby began to understand the importance of transportation within the modern development of the United States, particularly in light of the emergence of supersonic transport. He decided that it was essential that the transportation sector be given a voice when presidents made decisions affecting transportation policy.

With the support of Charles Schultz, the director of the budget; Joseph A. Califano, Jr., a special assistant to President Johnson and various officials at the Department of Defense, Halaby approached the president with concrete plans to create the USDOT. In August 1965, Johnson selected Alan S. Boyd, a former head of the Civil Aeronautics Board, to head

a task force assigned to set up the new department. Boyd subsequently became the first secretary of transportation.

The USDOT was in operation by April 1, 1967, employing some 95,000 employees, making USDOT the fourth-largest cabinet-level department. Initially, the USDOT was responsible for all areas of transportation in the United States. It held responsibility for the Federal Aviation Administration, the Federal Highway Administration, the Federal Motor Carrier Safety Administration, the Federal Railroad Administration, the National Highway Traffic Safety Administration, the Federal Transit Administration, the Maritime Administration, the Saint Lawrence Seaway Development Corporation, the Research and Innovation Technology Administration, the Pipeline and Hazardous Materials Safety Administration, and the Surface Transportation Board.

Departmental Evolution

Over time, the USDOT evolved in response to changes in the political and social scene, as well as to those within the transportation sector. Responsibilities for mass transit were transferred to the Department of Housing and Urban Development in 1968. Under the Jimmy Carter administration (1977 to 1981), it was recommended that the Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration be combined into the Surface Transportation Administration.

In 2002, the Homeland Security Act, which signaled widespread government reorganization in the wake of the terrorist attacks of September 11, 2001, transferred oversight of the U.S. Coast Guard and the Transportation Security Administration, which had been initially established as Department of Transportation Operating Administration, to the Department of Homeland Security. Within the USDOT, the Transportation Security Administration was established for the purpose of overseeing security at airports and in other forms of transportation.

About the Divisions

The Federal Aviation Administration is responsible for the regulation and oversight of all civil aviation in the United States, including passenger and cargo flights, commercial space transportation, pilot certification, civil aviation safety standards and

practices, air traffic control, the control of aircraft noise, and the environmental impacts of aviation.

The Federal Highway Administration administers the Federal Aid Highway Program, consisting of those highways funded in whole or in part with federal money, and the Federal Lands Highway Program, which is responsible for highway operation on lands owned by the federal government. In the latter role, the FHWA it works closely with land management agencies such as the National Park Service. The FHWA is also responsible for the *Manual on Uniform Traffic Control Devices*, which defines federal policy on traffic control devices, and sets the standards for traffic signs and signals and road surface markings.

The Federal Motor Carrier Safety Administration regulates the American trucking industry and is responsible for commercial truck and bus safety, among other areas.

The Federal Railroad Administration is responsible for safety regulations related to the railroads, as well as for developing national railroad policy.

The United States Maritime Administration (MA) maintains the National Defense Reserve Fleet for use in national emergencies, and promotes and operates the Merchant Marine and the U.S. Maritime Service, which trains officers for the Merchant Marine. The MA is also responsible for developing maritime trade routes, maintaining the shipyard facilities and other equipment related to national defense, and conducting maritime transportation research.

The National Highway Traffic Safety Administration (NHTSA) develops and enforces regulations related to motor vehicle safety, fuel economy, and motor vehicle theft resistance, and operates the vehicle identification number system. The NHTSA also develops crash test dummies and protocols used in vehicle safety tests. The data it produces on vehicle safety is used to develop transportation policy not only in the United States but throughout the world because of its depth of information.

The Pipeline and Hazardous Materials Safety Administration was created in 2004 and charged with the regulations for the operation of pipeline transportation in the United States, as well as transportation of hazardous materials. Its Office of Pipeline Safety maintains the National Pipeline Mapping System as part of its role in regulating the industries that use the pipeline system.

The Research and Innovative Technology Administration (RITA) was created in 2005 to coordinate the DOT's research and education programs, and it combines several older agencies, including the Transportation Safety Institute; the Joint Program Office for Intelligent Transportation Systems, which researches smart highways and other areas; and the Bureau of Transportation Statistics. Research areas in RITA include climate change, remote sensing and spatial information technologies, intelligent transportation systems, and other activities.

The Saint Lawrence Seaway Development Corporation is responsible for marine traffic in the Saint Lawrence Seaway between Lake Erie and Montreal, Canada. On the other side of the border, the Canadian Saint Lawrence Seaway Management Corporation shares the same duties.

The Surface Transportation Board inherited the railroad-related regulatory powers of its predecessor, the Interstate Commerce Commission, including regulations concerning the acquisition or construction of rail lines, the mergers of railroad companies, and the rates set by railroad companies.

The Transportation Security Agency, an agency in the Department of Homeland Security, is responsible for overseeing the security of transportation systems inside or connecting to the United States.

Secretaries of Transportation

By 1988, eight individuals had served as secretary of transportation under administrations from Lyndon B. Johnson to Ronald Reagan. In order of service, those eight secretaries included Alan S. Boyd, John A. Volpe, Claude S. Brinegar, William T. Coleman Jr., Brock Adams, Neil E. Goldschmidt, Andrew Lewis, Elizabeth Dole, and James H. Burnley, IV. In an empirical analysis of job performance conducted in 1988 for the Eno Foundation's Center for Transportation, John L. Hazard, a professor of marketing and transportation, examined overall job performance of those eight individuals, paying particular attention to budget success, legislative output, decision-making abilities, and contributions to national development. Hazard concluded that Andrew Lewis and John A. Volpe had been the most successful at heading up the USDOT and contended that Elizabeth Dole, Neil E. Goldschmidt, and Brock Adams had done the least to promote the needs of the transportation industry.

Into the 21st Century

In 1997, during the administration of Bill Clinton, the Committee on Transportation Research and Development, an interagency group, released *Transportation Science and Technology Strategy* in which the committee laid out its recommendations for bringing the American transportation sector into the 21st century. Two years later, a more comprehensive supplement to that strategy was released.

Together, the plans recommended a four-tier strategy for the role of the USDOT in developing the science and technology of American transportation. The first tier dealt with the planning and research involved in developing transportation policies in a rapidly changing world. The second tier laid out goals for forming essential partnerships that would promote the formation of new research and policies on vehicles, global air transportation, improved weather services, enhanced transportation of goods and freight, and meeting the transportation needs of the aged and disabled populations.

The third tier was concerned with enabling research into areas such as communications, designs, and national transportation strategies. The fourth tier was involved with educating and training the public and those individuals and agencies responsible for bringing transportation research and policies to fruition.

By the 21st century, the USDOT was devoting a good deal of attention to the research recommended in the two reports of the 1990s, focusing on transportation safety, mobility, human and natural environments, economic growth and trade, and national security, which has been at the forefront of the USDOT's agenda since 9/11.

During his 2013 State of the Union address, President Barack Obama proposed a "Fix It First" program designed to boost the still-shaky economy by putting Americans to work in the transportation sector.

He suggested that individuals involved in the program could be employed in the repair of 70,000 bridges that had been deemed structurally unsound, and proposed the Partnership to Rebuild America, which seeks to form partnerships with the private sector to modernize ports, improve transport of goods, storm-proof pipelines, and improve schools throughout the United States.

In Obama's 2014 budget, the USDOT was allotted \$77 billion, an increase of 6 percent over the

2012 budget. An additional \$50 billion was earmarked for revitalizing the transportation sector by investing in key areas.

The USDOT continues to work closely with state and local governments, other federal agencies, and the private sector in conducting research and in developing policies that meet the needs of a country that is increasingly affected by advancing technologies in all areas of transportation.

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See Also: Bureau of Public Roads; Department of Transportation Act of 1966; Federal Aviation Administration; Federal Highway Administration; Federal Motor Carrier Safety Administration; Federal Railroad Administration; Federal Transit Administration; Maritime Administration; National Highway Traffic Safety Administration; Pipeline and Hazardous Materials Safety Administration; Surface Transportation Assistance Acts of 1978 and 1982; Surface Transportation Board; Transportation Policies, North American.

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Value Increment Tax

The value increment tax (VIT), also variously known as the land value increment tax, land capture value tax, betterment levy, and valorization tax, is levied to capture the increase in land value that can be attributed to public investment. The tax has traditionally been proposed when the public sector is considering an infrastructure improvement, such as a subway, highway, school, park, or any other investment that increases the value of adjacent land.

Both the special assessment tax and the tax increment financing tax are variations of the value increment tax. With special assessment, the municipality levies the tax only on those who directly benefit from the improvement. Perhaps the most common form of land value increment tax in the United States is the tax increment financing district (TIFs) authorized by 48 states. Studies have shown that transportation investments have a definite impact on land value, and thus land value increment taxes are often used to finance transportation projects.

The Principle of Land Value Capture

The value of land increases when land owners fund improvements. Publicly funded investments such as improvements to infrastructure and the provision of public services can also increase the value of land. Value capture is a means for government

to recapture a higher proportion of what economists call the “unearned increment,” increases in land value that are a result of governmental actions rather than the owner’s efforts.

Similar to the site value tax in that both tax the unearned increment, the VIT differs from site value taxes in applying only to the portion of the unearned increment that is the direct result of public investment, and its purpose is to fund public investments that will raise the value of the land. Unlike property taxes, VITs do not increase with the landowner’s improvements.

Conventional property tax allows the government to capture some of the increased value of land, but the amount may be less. Moreover, because the VIT does not tax buildings and other improvements based on expenses the landowner has incurred, property owners additionally benefit from the greater value they have created at their own expense.

The VIT also has common ground with the capital gains tax on property, which levies tax on the increase in value between the acquisition price and the sale price of the land. Neither the VIT nor the capital gains tax would include in the tax assessment improvements made by the property owner only the VIT would isolate the increase in value arising from public investment as the basis of tax assessment.

The idea of the VIT is not new. Popularized in the 19th century by American political economist

Henry George, who based his arguments on earlier thinking by British political economists David Ricardo and John Stuart Mill, the central proposal was a single tax on the unimproved value of land. George believed that revenue generated by his land tax would be adequate to make all other taxes unnecessary, while at the same time avoiding the discouragement to production that was indivisible from a system based on property taxes.

Although a pure application of George's single-tax proposal is unfeasible, split rates whereby land and structures on it are taxed at different rates, with the larger portion of the combined tax rate applying to land assessments, has been adopted in some locations, including the state of Pennsylvania. As revenue from traditional sources has declined and urban population growth requiring larger investments in infrastructure has increased, value capture taxes have gained greater attention within the United States.

Special Assessments and TIFs

A special assessment is a real property tax proportionally levied on homeowners and landowners to cover the costs of public improvements that will benefit all upon whom the tax is levied. A municipality or a special district will make a decision to levy a tax for a particular improvement, such as a sidewalk or a sewer connection for a single street or a particular community. Since only those owners in the specific area will benefit from the construction, the special assessment tax is levied only against them. Typically, it is a one-time tax for a specific period of time.

All 50 states authorize special assessments, but financing mechanisms vary. For example, a municipality may issue bonds for a large infrastructure project, and the special assessment period will end when the bonds are paid off. For a more localized project, the city may choose to assess separate fees through property taxes or other assessments on a per unit (acre, square foot, etc.) basis.

Unlike special assessment, which can be used for improvements in the most affluent neighborhoods, TIFs were designed to revitalize blighted areas. First enacted in California in 1952, TIF legislation was eventually adopted by 49 states. California abolished TIFs in 2011, but they continue to be a popular means of financing infrastructure investments throughout all regions of the United States.

Under a TIF, an area is marked for revitalization and redevelopment; the annual property tax within the area is frozen at a base year, usually the year the project is authorized. It is expected that property values and taxes will increase once the improvement is made, and for a predetermined period (ranging between 15 and 50 years), the incremental property tax generated accrues to the TIF. Once the period expires, the increased revenue reverts to the municipality.

Generally, the TIF agency borrows money to fund the improvement project and pays the debt with money generated from the tax increment. Unlike other land value capture taxes that collect the tax increment before the improvement is made, TIFs collect after land value increases.

However, TIFs have been criticized for corruption and abuse, particularly in loosely defining blighted areas, and other taxing authorities such as school districts have protested their own loss of funds from increased property taxes. As a result, several states have reformed TIF legislation.

Land Value Taxes and Transportation

The 2008 Report of the National Surface Transportation Policy and Revenue Study Commission, *Transportation for Tomorrow*, advised that the country needed to invest at least \$225 billion annually from all sources for the next 50 years to upgrade the existing transport system to a state of good repair and create a more advanced surface transportation system.

The report also noted that present spending is only about 40 percent of the recommended amount. As more fuel-efficient vehicles and higher gas prices have affected fuel consumption and placed pressure on conventional sources for transportation finance, cities and states have turned to alternative means of raising revenue. VITs have been one of the strategies widely implemented.

Special assessment districts in northern Virginia will provide up to \$1 billion in funding for a \$6 billion, 23-mile (37-kilometer) extension of the region's Metrorail system being built in two phases. A Virginia law allows property owners to petition to tax themselves to pay for transportation improvements. Under this statute, 64 percent of local property owners approved a special assessment tax that will generate up to \$400 million from a tax of 22 cents per \$100 of assessed value on commercial and

industrial properties near the transit corridor. Additional funding is being drawn from federal transit grants, toll road revenues, and other sources.

Property assessments have helped fund new streetcar lines in Tampa, Florida; Seattle, Washington; San Francisco, California; and Kansas City, Missouri. The Atlanta Downtown Improvement District, a longtime champion of the city's new streetcar line, approved an allocation for transit from the district's ongoing funding of up to \$20 million over 20 years, split between construction and annual operating contributions. Funds are generated from an annual assessment of five cents per \$1,000 of assessed commercial value on 200 city blocks.

Three transportation projects in central Chicago were funded by TIFs. These projects include the Randolph/Washington station, the Dearborn subway, and various transit projects within central Chicago's "Loop." The city allocated \$42.4 million in TIF revenue to the Randolph/Washington station.

Portland, Oregon, designated the city's Gateway community as a TIF in June 2001, with a \$164 million budget to span 20 years. Both private and public developers have participated in projects, including a new transit center, a new medical building, low- and moderate-income housing, realignment of dangerous intersections, wider sidewalks, increased pedestrian lighting, and other infrastructure improvements.

With tighter purse strings at both the federal and local government levels, it seems likely that VITs will become an increasingly common tool in transit funding. Their clear connection from transit investment to the enhanced accessibility and connectivity that new transit brings, and to increased property values, makes the concept of "betterment taxes" more than a convenient political term.

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See Also: Economic Development; Tax Increment Financing Districts; Transit Finance.

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Value Pricing

Value pricing represents a regulatory system that uses a variety of fees and surcharges to create variable prices for transportation that, in theory, make the cost of certain choices a truer reflection of the consequence of those choices. Because the individual cost of using a transportation network may be considerably below the marginal social cost, value pricing seeks to narrow or close this difference so that the user, rather than society, bears the costs of its shipments or movements.

Movement of vehicles and people takes a toll on the infrastructure that supports transportation, as do weather conditions and time. A lack of revenue has made maintaining the transportation infrastructure difficult for many municipalities, local governmental authorities, and state agencies. Value pricing seeks to transfer the cost of congestion, pollution, and wear and tear on the roads to the users of the transportation system. In addition to promoting equity, value pricing is seen as a way to help individuals, businesses, and organizations better understand the true cost of their transportation choices and encourage them to make wiser and more thoughtful selections as a result.

As the fate of federal tax revenues continues to be an issue of contention in the United States, value pricing is likely to grow in popularity as an option to fund transportation systems.

Background

The use of motorways, rail, air, or water for transportation has certain costs. Roads, bridges, runways, locks, ports, and other transportation infrastructure undergo wear and tear as a result of usage. Each trip or journey causes congestion and



A congestion pricing notice in London, England, in 2012. London's fee for drivers to enter the city center reduced congestion within the designated zone by more than 25 percent and led to an increase in bus ridership.

pollution. When vehicles or ships are kept in one place, land is consumed for parking, which harms the environment by removing wildlife habitats or wetlands from the ecosystem. Paved roads and runways divert rainfall, causing erosion and flooding.

While these costs are constant, government agencies and legislative bodies often defer maintenance on needed work, driving up the ultimate cost of repair or replacement. Additionally, costs of building and maintaining transportation infrastructure have traditionally been masked, as taxpayer monies subsidize roadways, airports, waterways, and other modes of transportation, making the cost of travel or transport appear less expensive than it really is.

Government subsidies offset many of the costs of transportation. The interstate highway system,

for example, was begun in 1955 as a means of better facilitating travel and transportation throughout the United States. Construction of the original network took over 35 years to complete and cost nearly \$500 billion in 2013 dollars, making it one of the largest public works projects ever undertaken. The interstate highway system was financed through a variety of sources, including tolls, bond issues, property taxes, and fuel taxes.

Nearly 40 percent of the funds that support the maintenance of the interstate highways are unrelated to users of the system. This subsidy makes it less expensive, for example, for trucks to deliver goods cross-country, but that is because of a hidden subsidy that provides an advantage over competition such as railroads, which own and maintain their own trains and railways.

Because state and local governments are responsible for maintaining and rebuilding the interstate highway system portions within their boundaries, the realization has grown that doing so takes money away from other worthwhile projects and services. The same is true for a variety of other transportation services, including ports, airports, waterways, and locks. To that end, many municipal, local, and state governments have sought ways to transfer the costs of maintenance for transportation systems to the users who benefit the most from their existence.

Shifting Funding

The United States has a tremendous need for transportation infrastructure investment. A growing population and increasing numbers of motor vehicles have increased crowding on the roads and resulted in damage to the nation's transportation infrastructure. Decreasing tax revenues have resulted in many municipal, local, and state governments deferring needed maintenance to the transportation infrastructure. This has resulted in the decline of the U.S. transportation infrastructure, which according to some rankings, has declined from sixth-best to 23rd-best in the world in little over a decade.

Congestion alone causes tremendous problems, with the average urban worker losing the equivalent of eight full days at work as a result of traffic obstructions and delays. This lost time, combined with fuel costs, adds to a loss of between approximately \$900 and \$1,600 per year for most workers. As the public and lawmakers become better aware

of the hidden costs of a declining transportation infrastructure, consensus has grown for new taxes to rebuild it. Value pricing has been a key component in this movement, both as a way to generate funds and as a means of reducing congestion.

Value pricing can take place in a variety of ways. Some municipal, local, and state governments have instituted “dynamic tolls,” whereby tolls increase when congestion is heavy or at the more popular times of the day but decrease during less busy time periods. The city of San Diego, for example, has initiated the FasTrak system, which allows drivers of single-occupancy vehicles to travel in a special freeway lane otherwise reserved for buses and carpools. The toll for traveling in the FasTrak lane varies between 50 cents and \$8, depending upon time of day and demand for the service. Annually, the FasTrak program generates over \$1 million in tolls—money that is used to fund a bus service that would otherwise not be possible.

In the United Kingdom, the City of London instituted a similar program whereby drivers of automobiles are assessed a fee to enter into the heart of the city. The assessment of this entry fee reduced congestion within the designated zone by over 25 percent and led to an increase in bus ridership. While no city in the United States has attempted this to date, several, including New York City; Portland, Oregon; and San Francisco, have examined the concept.

Shippers of freight have also begun experimenting with value pricing as a means of increasing revenues as well as regulating the flow of shipments so that they become more consistent.

The Port Authority of New York and New Jersey, for example, struggled with the issue of congestion at its seven cargo terminals in the New York City area. These cargo terminals, which constitute the largest port on the eastern seaboard and the third largest in the United States, suffer the typical difference in congestion levels between peak and nonpeak hours. In response, the Port Authority investigated whether it could use value pricing to maximize the revenues generated during the peak loading and unloading times, which were from 6:00 A.M. until 10:00 A.M.

The Port Authority discovered that some shippers were operating under significant inventory cost constraints, so that pressure for the goods to be delivered made it worthwhile to pay a surcharge for an early delivery time. For other shippers, however, increased cost in unloading goods would diminish

their profits to such a degree that selecting an off-hours delivery made sense. As a result, fees were adjusted to a flexible schedule, with unloading during prime hours more expensive than at other times.

Other Uses

As the option of value pricing to increase revenues and reduce congestion has become more broadly disseminated, its use has spread to other areas involving transportation. Airlines, cruise ships, and other transportation services aimed at leisure travelers have adopted value pricing as a way to assist them in operating with a full contingent of customers, some of whom have paid more than others.

Airlines, which were deregulated in 1978, were hit by a price war during the 1980s and saw business plummet after the recession of 1990 to 1991. American Airlines, in response to the recession, undertook an examination of its business. It found that passengers could be broadly placed into one of two categories. The first category, leisure travelers, tended to be motivated by price, with flying being prohibitive if too expensive. The second category, business travelers, were focused on the length of flight times and were less concerned with price because their plans were less discretionary than those of the other group.

American Airlines found it could increase revenues by selling tickets on its flights for varying amounts, which would change depending upon availability of seats and the number of legs in a journey. Value pricing greatly increased revenue for American Airlines, as well as its competitors, because it brought the overall price of tickets down while forcing those with less discretionary plans to pay a premium. The success of value pricing by the airlines has spread to almost all other aspects of leisure and commercial travel.

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See Also: Airline Fares; Airline Industry; Highway Finance; Road Pricing Schemes, U.S. and International; Traffic Congestion; Transit Finance; Travel Pricing.

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Vans

A van is a box-shaped vehicle with a platform and four-wheel-drive power train similar to a truck with an enclosed back instead of the open bed of a pickup truck. The name is derived from "caravan," a covered vehicle. In the United States, most vans are in the light-truck vehicle class, which consists of motor vehicles designed for transportation of property and that have a gross vehicle weight rating less than 8,500 pounds. Some vans, especially commercial vans, are too heavy for this classification. Most vans can be driven with a standard driver's license (provided they are not used for school transportation) and are held to a fuel economy standard based on their footprint.

The modern van was developed by American car manufacturers in the 1960s, inspired by the popularity of the Volkswagen bus. The "chicken tax," a 25 percent tariff imposed on imported light trucks (including the VW bus) in retribution for the West German ban on American chicken, slowed the sales of the Volkswagen bus in the mid-1960s and allowed American manufacturers to better compete with it on price. These compact vans met a growing demand that the bus had helped inspire.

The front of the vans was typically short, with the engine mounted in the passenger compartment between the two front seats, at least in the case of the early Ford, Chevrolet, and Dodge vans. Full-size vans followed as the engine was transferred to the front of the vehicle with a short hood, and truck-like parts and features were added. Vans made an indelible mark on American popular culture in the 1960s and 1970s, such that the children of that era grew up to become the young parent demographic to whom minivans were then marketed in

the 1980s and 1990s, before the popularity of sport utility vehicles (SUVs) threatened the minivans' market share.

Types

There are numerous types of vans. The classic large, boxy van is called a full-size van, though modern full-size vans are more aerodynamic and curvy than their predecessors. While most vans are equipped with at least one set of back seats, they may be sold with only front seats, or rear seats may be removed by the owner in order to create a cargo van. The cargo hold of a cargo van may be accessible from rear-opening doors, side doors, or both, depending on the model.

Cargo vans are frequently used by people in trades that require them to transport equipment to a short-term work site, such as exterminators and animal control, home repair and home improvement, carpet installation, home media installation, air conditioning and heating work, cable and telephone repair and installation, and therapeutic massage. Musicians frequently use vans to transport their instruments, amplifiers, and other equipment. Cargo vans are also commonly used as delivery vehicles.

In the 1970s and 1980s, conversion vans were especially popular. They were full-size vans that had been outfitted by third-party companies to become something resembling a mobile living room. They ranged from the simple—in the 1970s, the conversion process often involved little more than carpeting the interior and adding seats, decoration, and a stereo system—to the complex, as many 1980s features overlapped with those offered by camper vans and included small kitchens and full entertainment centers.

Other vans are converted for business use by traveling sales representatives, media crews, and others who modify their vans to contain a small office in the back where work could be done on the road or while on assignment away from home.

The large passenger accommodation of full-size vans, which can transport up to 15 passengers depending on the model, has led to a number of passenger transport uses in cases where using one vehicle is of greater convenience than using several but using a bus is impractical. Children's outings can be planned around a van, for instance, reducing the number of adults whose services are needed to



Three European news organizations' vans were converted to carry satellite broadcasting equipment in 2010. The 25 percent tariff on imported light trucks in the United States, known as the "chicken tax," helped lead to the development of today's types of compact vans built by American manufacturers. The tax remains in effect after 50 years.

drive a vehicle as compared to cars, which can transport only four or five passengers.

Teenagers have long used vans to travel in groups to concerts and other events, reducing the number of legal drivers needed to take them where they're going. Churches, after-school programs, and other groups often use vans to take youth groups to outings and events, and community centers and retirement homes do likewise for the elderly.

Vans are easier than many other vehicles to convert for use by the disabled and can more easily be modified to accommodate a wheelchair. They are popular for use for paratransit for that reason.

Vans are also used to shuttle passengers between the airport and hotels, and between parking lots and final destinations (such as the workplace for commuters, or stadiums for sports fans), and in demand-responsive transit services such as Dial-a-Ride.

Minivans are smaller vans designed as passenger vehicles and have less cargo space than full-size vans, and usually less power; in some ways, minivans have more in common with a car than with a truck and are popular especially with families with

young children because the automatic rear doors make it easier to get babies and toddlers in and out of the vehicle. Until recently, nearly all minivans had front-wheel drive; four-wheel drive has become more common.

At the other end of the size spectrum within the passenger van category is the camper van, often just called a camper or RV (for recreational vehicle), which is taller than most vans in order to provide sleeping accommodations. The accommodations are not as complete as in motorhomes, however. Campers rarely include a toilet, though they may have a sink. Often there is a kitchen with a gas or electric heating element and a small refrigerator.

One type of commercial van is the step van. Step vans are used as delivery vehicles, especially for carriers with large delivery fleets, such as the postal service and its private-sector analogues, courier services, and similar businesses. They are also used for local deliveries by businesses that need to make deliveries to their customers on a daily or weekly basis, including commercial bakers, and are sometimes called "bread trucks" for that reason.

Step vans are constructed to be easily stepped in and out of by a driver who needs to do so frequently in the course of delivery work. In some cases, the sliding door is left open for most of the work period for further ease. These vehicles are similar in design, and in some cases, form the basis before modification to the utility vehicles used by some fire departments, police units, and other emergency responders as mobile command units.

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See Also: Light-Duty and Pickup Trucks; Paratransit in Developing Countries; Passenger Van Safety; Recreational Vehicles; School Transportation; Sport Utility Vehicles.

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Vehicle Emissions Standards

Vehicle emissions standards have emerged in various contexts over the last 40 years for a variety of reasons, and while diverse in approach, each program has the long-term objective of increasing the fuel economy of vehicles in the fleet. The first such measure was the introduction of the Corporate Average Fuel Economy (CAFE) standards. Following the 1973 Organization of the Petroleum Exporting Countries (OPEC) oil crisis, the U.S. Congress passed a series of measures to lessen the country's dependence on imported oil, including the CAFE standards, which required the car industry to increase the efficiency of vehicles (cars and light-duty trucks), with requirements weighted by vehicle sales, in the United States.

Different limits were set for both passenger cars and light trucks, which contributed to some of the

challenges that the standards have faced since their introduction. Indeed, the CAFE standards have been the subject of much controversy and criticism over their lifetime.

People drive much more today than they did in the 1970s and ownership patterns have also changed, with more consumers choosing sport utility vehicles (SUVs) and light trucks over conventional passenger cars; the former, by nature, are less fuel efficient. Because of these factors, combined with automobile manufacturers' focus on improving the internal combustion engine (ICE) rather than on developing alternative fuels and vehicles, CAFE has done little to actually reduce the total fuel consumption of the U.S. road-based fleet.

CAFE Standards

The U.S. Congress initially set fuel economy standards for passenger cars at 18 miles per gallon (mpg) from model year (MY) 1979. This standard was due to run through to 2002, but in 1985, it was increased to 27.5 mpg.

The light-truck standard was set at 20.7 mpg in 1979 and this standard ran through to 2002. The standards for light trucks was increased to 22.2 mpg for MY 2007.

The Energy Independence and Security Act (EISA), which came into force in 2007, changed the way in which the CAFE standards could be set. The revised rules set standards for MY 2020 for light trucks, passenger cars, and SUVs in combination. It stated that the manufacturers' combined fleet average must be at least 35 mpg for MY 2025. Medium-duty trucks were subsequently added to CAFE regulations from 2012, with regulation of heavy-duty commercial trucks introduced in 2014.

In 2009, a landmark agreement between the President Barack Obama administration, the states, and the car industry was made to harmonize the existing efforts under "one national program" delivering fuel-economy standards, but also delivering greenhouse gas emissions (GHG) reductions at the same time. The key stakeholders in the partnership are the National Highway Traffic Safety Administration (NHTSA), a branch of the U.S. Department of Transportation (DOT), the U.S. Environmental Protection Agency (EPA), and the California Air Resources Board (CARB).

The NHTSA and EPA are responsible for setting the fleetwide fuel-economy standards and the

GHG standards, respectively; and CARB is responsible for ensuring the delivery of the standards for those states that have subscribed to the more stringent greenhouse gases standards set by California in 2002 (which accounts for around 40 percent of the national fleet), and for ensuring consistency so that the country as a whole is working to one of the two standards.

Working together, the partnership split the period 2012 through 2025 into two phases. In 2010, the parameters for the 2012-to-2016 period were set with the aim of delivering 35.5 mpg in MY 2016, and the carbon dioxide (CO₂) per-mile standards were set by EPA at 250 grams for the same time period. CARB has agreed to comply with these standards. Phase two of the program, which will cover the period from 2017 to 2025, will see the standards reduced to 163 grams of CO₂/mile in terms of tailpipe emissions and 54.5 mpg in terms of fuel economy.

It is expected that a combination of efficiency measures and the adoption of alternative vehicle technologies will be utilized in order to achieve the fuel economy and GHG tailpipe emission reductions. A midterm review using the latest available data is due no later than 2018 for the remaining period to 2025.

California's Low Emission Vehicle Program

California has a history of preemption with regard to air quality standards in the United States because its Air Resources Board was established in 1967, predating the 1970 amendments to the 1963 Clean Air Act. California can go over and above federal standards and is the only state allowed to set such parameters. It is therefore not surprising that a number of developments surrounding clean cars have subsequently come from the state.

The Low Emission Vehicle and Clean Fuels regulation was introduced by the California Air Resources Board in September 1990 and became informally known as LEV I. It was the first program to link measures addressing fuel and vehicle technologies as a system, as opposed to focusing on one aspect or the other.

This law introduced six emissions categories: Zero Emission Vehicles (ZEV), Transitional Low-Emission Vehicles (TLEV), Super-Low-Emission Vehicles (SLEV), Partial Zero-Emission Vehicles (PZEV), Ultra-Low-Emission Vehicles (ULEV),

and Super-Ultra-Low-Emission Vehicles (SULEV). LEV I was concerned with conventional air pollutants, as opposed to GHGs. Specific mandates were also made at the time for the introduction of ZEVs; it required 2 percent of all vehicles brought to market by auto manufacturers in California by 1998 to fulfill zero-emission criteria.

Following the Clean Air Act Amendments of 1990, the U.S. government also set emissions standards for light-duty vehicles, with Tier I emissions standards phased in from 1994 to 1997 and Tier II standards from 2004 to 2009. A transitional National Low Emission Vehicle (NLEV) standard program was also run between 1999 and 2003, adapting the national standards to account for California's stricter standards.

While a relatively unheard of concept before the introduction of the regulation, the ZEV mandate component of LEV I emerged as the primary, and also the most controversial, outcome of the program; it is now considered a standalone policy while the other components of LEV I have progressed separately.

LEV I covered the period between 1994 and 2003. Following its introduction, other states in the country wanted to apply California's—as opposed to federal—standards. More than 10 states and the District of Columbia now adhere to California's standards. LEV I was reviewed in 1996 and subsequently LEV II standards were introduced in 1998 to cover the period from 2004 to 2010.

CARB adopted LEV III amendments to the regulations in 2012, both making criteria pollutant standards more stringent and including GHGs for passenger vehicles in the standard. These updates will be introduced across MY 2015 through 2025.

Renewable Fuel Standard

The Renewable Fuel Standard (RFS) is a federal program managed by the EPA that was introduced by the Energy Policy Act of 2005. It was subsequently expanded by the EISA in 2007. Its primary focus is increasing the amount of renewable fuel contained in conventional fuels year-on-year, rising to 36 billion gallons by 2022. There are several categories of renewable fuel (including cellulosic biofuel, total advanced biofuel, and biomass-based diesel) included in the standards, but each of these fuels must be lower in emissions than the fossil fuel that it is replacing.

Low Carbon Fuel Standard

Distinct from the RFS are the recent developments that have taken place with regard to Low Carbon Fuel Standards (LCFS). The most common low-carbon fuels include biofuels, gases such as compressed natural gas (CNG) or liquefied petroleum gas (LPG), electricity, and hydrogen, although these are technologies that have not yet achieved mainstream market penetration.

The LCFS has gained prominence over the last five years; CARB was the first authority to establish an LCFS in 2007, which was adopted in 2009 and implemented from 2010. California's program seeks 10 percent reduction per unit of energy by 2020. Similar standards have subsequently been adopted in British Columbia and Ontario in Canada. Several other U.S. states including Maine, New York, Massachusetts, and Pennsylvania are considering proposals to adopt an LCFS following California's developments in this area.

In Europe, the Biofuel Directive mandated European Union (EU) countries to include biofuels in their fossil-based transport fuel, with the aim that by 2010 5.75 percent of all transport fuel would be replaced by biofuel substitutes. The United Kingdom (UK) also introduced a Renewable Transport Fuel Obligation Program (RTFO), requiring transport fuel suppliers to ensure that 5 percent of fuel for road-based vehicles would come from sustainable (primarily biofuel) sources by 2010.

Both programs have been largely unsuccessful as a result of two shortcomings. First, the regulations were not based in the carbon intensity of the fuels, allowing the directive to have very little impact on reducing GHGs from total fuel consumption. Second, as has been the case in the United States and elsewhere as well, the land use and food production challenges that have emerged since the introduction of the directive, the RTFO, and subsequent policies have resulted in mass opposition to the promotion of biofuel substitution.

Cars and CO₂

Standards specifically dealing with GHGs have been developed outside the U.S. context, too. Regulations (EC) NO 443/2009 (Cars and CO₂) was a bill that went into force in Europe in 2009 following the failure of the European car manufacturers to reduce tailpipe emissions through industry-led voluntary agreements. Cars and CO₂ mandates that

100 percent of new cars sold in 2015 should emit no more than 130 grams of CO₂ per kilometer, rising to 95 grams of CO₂/km by 2020.

While the bill does not specify how these targets should be achieved, giving the car companies a relative amount of freedom to use a mix of vehicle improvements and alternative fuels, it allows for an "integrated approach" whereby the bulk of emissions are reduced by fuel-efficiency improvements, with the additional amount being achieved by "complementary measures." A lack of clarity as to what is covered under the additional provisions endures while the auto industry pushes ahead with delivering against the targets set by the regulation.

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See Also: Air Pollution, Automobiles; Air Pollution/Air Quality; Green Fuels; Hybrid Automobiles/Hybrid Electric Vehicles; Low-Emission Vehicles; Zero-Emissions Vehicles.

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Vehicle Fleet Emissions

It is becoming increasingly accepted that climate change is not only a consequence of natural temperature fluctuations but that human activities are enhancing these natural variations through the

emission of carbon dioxide (CO₂), nitrous oxide, methane, and hydrofluorocarbons (cumulatively known as the greenhouse gases) into the atmosphere.

One of the most significant contributors to greenhouse gas emissions is the transportation industry. The rapidity of growth in the passenger vehicles market experienced over the last few decades has provoked intense interest and regulatory activity. Controlling and limiting the emissions of passenger vehicles is a widely adopted approach falling under the broader international commitments toward mitigating and adapting to climate change.

With the number of cars on the world's roads exceeding 1 billion and the appetite for car travel and car ownership growing, many countries have looked to the mechanisms available to reduce the environmental impacts of the car industry. While some countries have had some measures in place for decades, whether voluntary or regulatory, other countries, particularly industrializing countries such as Brazil, Russia, India, and China (the BRIC countries) are beginning to recognize the need to take action on tailpipe emission limits. Regardless of the longevity of mechanisms encouraging reductions in passenger vehicle emissions, it is clear that the automotive industry is one of the most regulated industries.

Clean Air Act and Amendments

Per capita greenhouse gas emissions in the United States are four times the world average, according to the World Resources Institute, and the transportation sector accounts for approximately 30 percent of the nation's total emissions. The Clean Air Act (CAA), incorporated in the US Code as Title 42, Chapter 85, along with its amendments (CAAA) in 1990, establish under Title II, s.202 emission standards for new motor vehicles or new motor vehicle engines.

The CAA specifies that emission standards are to be based upon establishing classes or categories of vehicles or engines, and that these categories should be based on gross vehicle weight, horsepower, type of fuel used, or "other appropriate factors."

The rationale for using weight as a means of setting classes (or bins, as they are known) was grounded in the findings of studies that examined the effects of vehicle weight and size on accident fatality risk and concluded that reducing vehicle weight is the most significant factor in decreasing the number of fatalities. Therefore, adopting

advanced lightweight construction not only significantly reduces CO₂ emissions at the tailpipe but also contributes to road safety and accident prevention.

Corporate Average Fuel Economy Regulations

Enacted by the U.S. Congress, the Corporate Average Fuel Economy (CAFE) Regulations set fuel consumption standards for vehicles and light trucks, which applied to the overall fleet sold in a given year by a manufacturer. These emission standards for light-duty vehicles have been phased in through tier standards.

Tier 1 standards were phased in progressively between 1994 and 1997. The standards applied to all new light-duty vehicles (LDVs), including passenger cars, light-duty trucks, sport utility vehicles (SUVs), minivans, and pickup trucks. Vehicles included were identified by a gross vehicle weight rating (GVWR) of less than 8,500 pounds.

Congress left the levels of fuel economy of light-duty vehicles to be set by the Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration. These targets were much less stringent than those established for passenger cars, and the industry responded by adding weight to vehicles. This experience showed that by subjecting heavier vehicles to less stringent targets, the regulations encouraged manufacturers to increase the mass of smaller vehicles to bring them outside the purview of regulatory measures.

Tier 2, which was adopted in 1999, introduced more stringent emission limits and made changes to the standards in order to address the issues of emission reduction avoidance through adding weight to vehicles. Tier 2 increased its scope to cover medium-duty passenger vehicles (MDPV) rated between 8,500 pounds and 10,000 pounds GVWR and used for personal transportation.

Those vehicles with heavier engines and identified as commercial vehicles are regulated under the heavy-duty engine emission standards. Engines in commercial vehicles above 8,500 pounds GVWR, such as cargo vans or light trucks, continue to certify to heavy-duty emission standards under 40 Code of Federal Regulations (CFR) Part 86. It is telling, not only in the early limited effectiveness of the U.S. CAFE Regulations, but also by the extension of scope to include larger vehicles under Tier 2, that capturing vehicles that traverse the boundary between passenger and commercial vehicles, either by definition

or by weight, can have a significant impact on the achievement of reduced CO₂ emissions.

The proposed rule for Tier 3 was signed by the EPA on March 29, 2013. The proposal introduces new emission standards and reflects the more stringent emission standards already established in the California emissions regulations (LEV III) standards. The structure of Tier 3 standards is similar to the Tier 2 standards in that manufacturers must meet fleet-average emission standards for their vehicles in a given model year.

Proposed Tier 3 standards include a fleet average non-methane organic gas (NMOG) and nitrous oxides (NO_x) limit that must be met by each manufacturer. The fleet average NMOG + NO_x limit is to be phased in starting from 2017 and introduces a level of 30 milligrams/mile in 2025. Importantly, the Tier 3 fleet average limit is applicable to all vehicle categories.

California Emission Standards

California emission standards have traditionally been more stringent than the EPA requirements, with other states, including Oregon, New York, Florida, Maryland, and New Mexico, choosing to adopt the California low emission vehicle (LEV) standards. Differences include that the same standards are applied regardless whether the vehicle is diesel or gasoline fueled.

Although the California LEV II program was similar in structure to the federal Tier 2 legislation, there were a number of differences regarding overall fleet emission stringency, durability, and categorization of vehicles. One difference was that the federal approach uses eight certification “bins” to allow averaging across a greater level of emission diversification in the fleet. Another important difference is that in 2010, the federal fleet average NMOG emissions, around 0.090 g/mi, based on Bin 5, was more than twice as high as the LEV II NMOG levels. This was a result of the wide scope of emissions covered by the standards.

California LEV III standards were adopted in early 2012 and will be phased in between 2015 and 2025. The LEV III standards modify the LEV II standards in several ways: (1) combining NMOG and NO_x standards into one NMOG + NO_x standard, (2) introducing a more stringent combined NMOG + NO_x fleet average requirement for 2015 to 2025 model years, (3) adding several emission

standard bins, and (4) increasing the durability requirements for emission control systems. It is of no surprise that the federal regulations have responded to the success of the California LEV standards by reproducing similar requirements under the proposed Tier 3.

European Union

In the European Union (EU), regulation of vehicle emissions was established initially as a voluntary measure. However, with slow progress being made by the industry, the European Commission adopted in 2009 Regulation (EC) 443/2009 (hereafter, the 2009 Regulation). The 2009 Regulation established mandatory CO₂ emissions reduction targets for passenger cars with an overarching target of 120 g/km for the entire average new car fleet to be reached by 2015. This target is set up to be reached gradually by manufacturers, with the longer-term target of 95 g/km as average emissions for a new car fleet from 2020.

These lead-in times, just like the phase-in times for the emission tiers in the United States, is based upon the understanding that the industry requires predictability and time in order to adapt to change. The reduction in CO₂ emission targets laid down in the 2009 Regulation is focused on a fleetwide average of manufacturers rather than a prescription for emission performance standards to be met by every passenger vehicle produced by a manufacturer independent of the segmentation. This enables heavier vehicles to have greater emission levels and these are intended to be offset by lighter, more-fuel-efficient models.

The way in which the 2009 Regulation envisages compliance with the CO₂ emission target is predominantly by means of improvement in vehicle technology, with a smaller reduction in CO₂ emissions obtained through additional measures in the form of “other technological improvements.” These factors include but are not limited to the following:

- The fitting of tire pressure monitoring systems
- The fitting of gear-shift indicators
- The promotion of low rolling resistance tires
- The reduction of emissions of specific fluorinated greenhouse gases in mobile air conditioning units fitted in motor vehicles

Manufacturers will be given a target based upon the sales-weighted average mass of their vehicles. The 2009 Regulation provides for flexibility in the way in which manufacturers choose to meet their targets; they can either meet them as an individual manufacturer on a fleetwide basis or alternatively decide to form a pool comprised of a number of manufacturers for the purpose of meeting their CO₂ emissions obligation. Where the manufacturer or pool fails to meet its specific emissions target an “excess emissions premium” will be applied on the basis of the number of new passenger cars manufactured.

The absence of measures within the 2009 Regulation placing CO₂ emission targets on heavier vehicle categories entitles manufacturers wishing to bring to market these sorts of vehicles the ability to omit these vehicles from the CO₂ emission reduction requirements. It also has the potential to encourage manufacturers to design heavier rather than lighter SUVs, the same type of perverse effect experienced in the United States following the introduction of the U.S. CAFE Regulations.

The EU blocked this possibility, however, through the adoption of a regulation setting emission performance standards for new light commercial vehicles as part of the EU’s integrated approach to reduce CO₂ emissions from light-duty vehicles.

Other Countries

Other countries with notable vehicle fleet emission reduction targets include, but are not limited to, Japan, China, Australia (only voluntary measures in place), Canada, and South Korea.

In Japan, legislation was introduced by the Ministry of the Environment to control nitrous oxide (NO_x) from vehicles under a 1992 law. The regulation was tightened in June 2001 and included new provisions relating to the control of particulate matter (PM). This 2001 law introduces emission standards for specified categories of in-use highway vehicles, including commercial goods vehicles regardless of the fuel type. The emission limits apply not only to new vehicles, but also to older vehicles already in use. To comply with the legislative duty, vehicle owners have two options. They can either replace their old vehicle if it does not meet the standard with a vehicle that does, or they can retrofit their old vehicle with approved NO_x and PM control devices. Japan is currently



A researcher at ManTech Environmental Technology in Denver, Colorado, performs an automobile emissions test on a chassis dynamometer, which cradles the car's wheels in rollers to simulate road driving during test procedures.

determining a standard for passenger car fuel economy for 2020.

Canada considers regulations to be vital in its efforts promoting clean transportation. To this end, the government of Canada has introduced greenhouse gas emissions standards for new cars and light trucks for the 2011 through 2016 model years. These standards harmonize with U.S. standards. Similar standards are forthcoming for new heavy trucks. In addition, Canada's Renewable Fuels Regulations 2010 require an average of 5 percent renewable content in gasoline and 2 percent renewable content for diesel fuel. These small steps have a positive cumulative effect on the level of vehicle emissions.

In New Zealand, the Land Transport Rule: Vehicle Exhaust Emissions 2007, which was amended in 2012, is the main measure for controlling vehicle emissions. It sets emissions standards for vehicles entering the New Zealand fleet and for those

operating on New Zealand roads. The rule requires vehicles to demonstrate that at the point of manufacture or modification they complied with, at a minimum, an approved vehicle emissions standard relevant to their class and fuel type.

While the market for passenger vehicles is accelerating rapidly with the economic growth China is experiencing, the China Ministry of Industry and Information Technology (MIIT) issued its proposed Phase III fuel consumption regulation for passenger cars, which is aimed at reducing the fuel consumption of new passenger vehicles to 167 grams of CO₂/km by 2015. Comparatively, this target appears less ambitious than other emissions reduction targets set for vehicles worldwide.

While vehicle fleet emissions are capped in a number of countries either by the setting of legislative minimum standards or through the introduction of voluntary emission reduction commitments, other strategies exist to reduce emissions. These measures include new automotive designs, fuel source alternatives (for example, the use of electric vehicles, hybrid vehicles, fuel cell technologies, and smart cars), the implementation of eco-driving techniques, car sharing or car clubs (for example, Zipcar), and vehicle and gas pricing policies (which can result in different consumer choices in relation to car purchase and to different transport mode choices). All of these strategies aim to increase efficiency and reduce the environmental effects associated with the automotive sector.

In addition, the economic downturn may encourage people to use or buy more fuel-efficient vehicles to save money, which will lower fossil-fuel energy use, reduce carbon emissions, and change the composition of the vehicle fleet.

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See Also: Green Fuels; Greenhouse Gases; Low-Emission Vehicles; Vehicle Emissions Standards.

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Vehicle Miles Taxation and Fees

Vehicle miles traveled (VMT) is the total number of miles driven by all vehicles within a given time period and geographic area. VMT is an indicator of the travel levels on the roadway system by motor vehicles and can be used to gauge a vehicle's impact on the roadway. VMT-based charges have been considered as an alternative or supplement to the existing fuel tax that supports federal transportation.

Fuel Tax Versus VMT-Based Tax

More than 75 percent of current federal highway funding and a large portion of the state funds come from motor fuel taxes. Fuel taxes encourage motorists to drive less, manufacturers to incorporate fuel-saving technologies in new vehicles, and consumers to choose more fuel-efficient vehicles. Less driving was done when the fuel prices went up in 2008, for example.

There is an increase in the manufacturing of fuel-efficient vehicles in the recent past, and consumers have started looking to these vehicles as a solution to lower their driving expenses. These fuel-efficient vehicles also generate fewer environmentally damaging emissions and lessen energy dependency, which are considered important by many consumers. However, there is a concern that, with the shift to more fuel-efficient technologies and alternate fuels, the fuel tax revenue will be reduced in the coming years.

In the current tax system, vehicles using fuels other than fossil fuels (especially electric vehicles)

will not be taxed. Another concern is that the fuel tax does not directly deal with the amount of driving. Because the vehicle fleet has varying fuel efficiencies, it is possible that a fuel-efficient car will drive longer distances and actually pay less tax than a less-fuel-efficient car that is driving smaller distance. One solution to both these problems, suggested by many, is a VMT-based tax.

How Does It Work?

The VMT-based system relies on measuring the number of miles driven by each vehicle. This is expected to be achieved through the use of on-board Global Positioning System (GPS)-based systems. It could be a separate unit or a part of a preinstalled GPS unit. The data collected could be manually read during an annual inspection or registration renewal.

Other options are VMT detection using localized infrastructure, such as tolling gantries and cell phone towers, or via satellites. Those charges could be based on selective facilities (certain highways) or geographical zones. The charges could potentially vary based on the vehicle type so as to take into consideration the varying amount of pavement damage a vehicle makes (for example, passenger car versus trailer trucks). These variable charges based on location and vehicle type could also be used in conjunction with congestion management approaches, which could include variable charges based on time of day.

Another important aspect is the method of payment of fees. The payment could be processed at the gas pump at the time of fueling or through periodic billing. For the consumer, charging at the pump would mean minimum change in the way they are charged now with a fuel tax. However, it would require systems to be installed at the gas stations. Periodic billing would require more sophisticated central systems but allows for weekly or monthly charging.

The Debate

The merits of a VMT-based tax have been debated for a long time in the transportation and public policy circles. The proponents of a VMT-based tax argue that it allows for a reliable and sustainable funding option. Because the steady supply of gasoline is uncertain and there is a move away from gasoline to alternate fuels, the tax based on fuel could

begin to vary considerably and become unreliable. The political reluctance of the public to increasing fuel taxes is also a concern.

A VMT-based tax is also more equitable because it is levied based on one's amount of driving and use of the road system. While the energy dependency on other nations and emissions are related to the fuel itself, the larger share of direct costs from maintenance of roadways, congestion, and accidents are related to the miles traveled. VMT-based tax also allows for varying charges for different vehicle types depending on the potential damage to the infrastructure. Thus, the system could optimize highway use by charging higher fees during congested travel times to assist in congestion management. The increasing adoption of technologies in vehicles to allow for monitoring the VMT is considered helpful in assessing the length and time of driving.

However, the critics of a VMT-based tax point to a number of problems associated with it. Unlike a fuel tax, the VMT-based tax does not offer an incentive for drivers to buy more fuel-efficient vehicles, which might hamper the move toward more environment-friendly transportation.

There are many concerns about privacy of drivers because the VMT system depends on tracking the movement of each vehicle, which in turn is a proxy for tracking the driver. Therefore, it would be important to ensure that the data collection process, storage, and use occur in a secured manner.

This system would have significant up-front costs for equipment and monitoring systems. The phase-in process could also take many years. Social equity issues (for example, people in rural areas might have to pay more because they are more isolated, and the poor might have to pay a higher proportion of their income than the affluent) need to be resolved.

Current Status

The gasoline price, gas tax, and VMT charges would behave as a system. Therefore, careful analysis of their relationships and different scenarios is required to arrive at sound public policies. Various agencies in the United States at the local, state, and federal levels have begun assessing the efficacy of vehicle mileage fees as a replacement for the current taxes or as a supplemental funding mechanism.

One of the first pilot studies carried out in the United States is the Mileage Fee Concept and Road User Fee Pilot Program by the Oregon Department

of Transportation (ODOT). Launched in 2006, ODOT equipped vehicles with onboard data collection units that recorded mileage driven within specific zones. Customers were charged a mileage-based fee at the gas pumps after subtracting the fuel tax. The study found that the system is viable without compromising customer privacy and comfort, as well as acceptance from the customers.

The University of Iowa Road User Charge Study sponsored by the U.S. Department of Transportation has found similar potential. This study covers locations in a number of states and participants varying in age and education characteristics. Outside the United States, Germany has a VMT-based fee system for trucks. Austria, Switzerland, and the Czech Republic also have similar systems.

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See Also: Highway Finance; Highway Trust Fund; Road Pricing Schemes, U.S. and International; Travel Pricing; Vehicle Miles Traveled.

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of the travel levels on the roadway system by motor vehicles. It is used by regional transportation and environmental agencies for planning purposes.

The Federal Highway Administration (FHWA) uses VMT and total lane miles to determine the distribution of federal funding among the states. VMT is routinely used not only to measure the amount of traffic on roads but to calculate important statistics including traffic fatalities, fuel efficiency, and air quality. VMT is influenced by factors such as population, age distribution, number of vehicles per household, and land use. VMT-based charges have been considered as an alternative to the existing gas tax that supports federal transportation funds.

Significance and Measurement

VMT has been a critical transportation indicator for many years. It gives a clear picture of a road's usage daily, weekly, monthly, or annually. Such information could then be aggregated to neighborhood, municipal, county, state, or national levels for various analyses. While VMT can be used for federal and state funding distribution, it can also indicate the changes in development and travel patterns in a geographical region. It can also show the most congested roadways and extent of sprawl.

The FHWA requires state departments of transportation (DOTs) to provide annual highway statistics including VMT estimates as part of the Highway Performance Monitoring System (HPMS), which divides roadways into 12 functional classes and traffic into four vehicle classes.

Defined by the FHWA, HPMS is "a national level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the nation's highways." State DOTs often collaborate with local governments and metropolitan planning organizations (MPOs) in collecting and reporting the traffic counts.

VMT is usually calculated from traffic counts taken on interstate, state, county, and city roadways. Traffic counters are electronic devices that can determine how many vehicles pass a specific point. Other traffic counts performed as part of the planning and design processes are also used in the state VMT calculation.

The HPMS data form the basis of the analyses that support the biennial Condition and Performance Reports to Congress. These reports provide

Vehicle Miles Traveled

Vehicle miles traveled (VMT) is the total number of miles driven by all vehicles within a given time period and geographic area. VMT is an indicator



A solar-powered automatic traffic counter in use on an Austrian road. A loop of sensors, seen here as rectangular lines in the pavement, registers passing vehicles. Traffic counts obtained from devices like this contribute to calculations of vehicle miles traveled, or the total number of miles driven by all vehicles within a given time period and geographic area.

a comprehensive, factual background to support development and evaluation of the administration's legislative, program, and budget options. They provide the rationale for requested Federal Aid Highway Program funding levels.

States usually take counts from a sample of highways and roads. The sampling sites represent a cross-section of functional class and traffic volume categories. The counters collect continuous traffic data and create a measure called average annual daily traffic (AADT). AADT is then multiplied by the distance measured to determine the total vehicle miles traveled for that section on the average day.

Multiplying this number by 365 will get the annual VMT. The localized traffic counts are aggregated to create VMT totals based on geographies, roadways, and vehicle types. Geographies could

be municipalities, counties, metropolitan regions, states, or the country.

The roadways are divided into urban and rural jurisdictions based on U.S. Census urban/rural boundaries. They are further divided into different functional classes—interstate, freeway, principal arterial, minor arterial, major collector, minor collector, and local streets. Usually, these data sets also collect information on vehicular types—passenger cars, buses, other passenger vehicles, single-unit trucks, and combination trucks.

MPOs use travel forecast models to estimate VMT in their jurisdictions. Though they are not actual counts, the model is calibrated with counts from more locations and functional classes than HPMS. This allows for a more robust estimation of VMT in the MPO region. However, the accuracy of

the estimation depends on the trip-generation and trip-distribution methods and parameters used in the network model.

Other data sources for estimating VMT include fuel sales, trip-making behavior, household size, household income, population, number of licensed drivers, and employment. These data can be obtained from the U.S. Census Bureau or from surveys.

Overall VMT Trends

In the United States, VMT is available by state, functional system, highway category, and vehicle type. The annual VMT, as well as the per capita VMT in the country, was increasing steadily over many decades until 2003, when the VMT started stabilizing and showed a decline from 2008.

VMT is a function of economic activity, transportation price, transportation supply, and sociodemographics. The stabilizing of VMT could be attributed to the stabilization in the above-mentioned factors. A more dramatic decline can be seen in the per capita VMT, which is the result of a combination of reduced growth in population and people's driving. The decline in VMT in the last five years or so could be attributed to high fuel prices and the affinity of the younger generation to live in downtown areas and closer to work places.

Factors Influencing VMT

There are many factors affecting the increase or decrease in VMT. Because VMT is the result of vehicular travel, the number of drivers and types of vehicles on the road are the most important factors in estimating whether VMT will increase or decrease. As the population increases, the number of potential drivers also increases. If these added people drive their own vehicles, VMT will obviously increase.

Because owning a vehicle is related to an individual's economic condition and affinity for or dependence on owning a vehicle, VMT increases in better economies, especially when people prefer to own vehicles. However, if the individual prefers not to drive a vehicle but to use transit, biking, or walking, the VMT might not go up.

Thus, the state of the economy, number of drivers, and number of vehicles directly influence the VMT. As mentioned, the mode of travel also matters. Even if the population increases, if the added travelers choose to use transit or carpool instead

of an individual auto, VMT can stay low. The same effect is possible if they prefer to bike or walk to their destinations.

The land development pattern has a large influence on the travel modes and VMT. In a concentrated development, people live, work, and shop close by and the need to travel by vehicle and the distance traveled will be low. One of the reasons for increased VMT is the sprawling land development pattern. Sprawl is the dispersion of land development to the suburbs and rural areas typically with low-density development. Such development is associated with new roads and longer travel distances. It also causes serious destruction of forest and agricultural land as well as waterways and wetlands. Such a development pattern also allows for more biking and walking.

However, in a "sprawl" development, people live farther from central business districts with residential, commercial, and office uses separated from each other. Such a development pattern necessitates more and longer travel by vehicles, often individual automobiles.

Both demand and supply factors play a role here. Sprawl development demands more roads. In response, developers, municipalities, and transportation agencies construct more roadways. This additional supply of roadways propels more travel.

Added road supply could also be a response to issues such as congestion. In order to relieve congestion in an area, alternate routes might be developed. An unintended consequence, again, is more travel. This is a result of phenomenon called latent demand.

Many people decide not to travel during the most congested time periods or use alternate travel modes when there is congestion in the area. However, if there is extra supply of roads, these same people could decide to travel at busier times or move back to their own vehicle from an alternative, thus increasing the demand. This increased demand will balance out the additional supply added through extra lanes or additional roads.

Telecommuting options are expected to reduce the work-related VMT. However, its impact on overall VMT could be low.

Fuel price and transportation price are key factors influencing VMT. As fuel prices increase, the tendency for people to drive alone goes down, thus reducing VMT. This trend was prominent after

2008, when gas prices went above \$4 per gallon in many parts of the United States. This might foreshadow a situation where VMT will reduce drastically only if the gas prices go significantly higher in the future.

However, it should be noted that, historically, gas price inflation is followed by a deflation and corresponding spike in VMT. Because the VMT did not go back to pre-2008 levels after the price deflation following the 2008 high, it could be assumed that there are other factors influencing the reduction in VMT.

The price of travel also matters. High toll prices, congestion charges, and parking charges have tended to reduce the VMT. This is partly by people cutting down on the inefficient trips and encouraging trip chaining, carpooling, and nonmotorized travel.

Issues With Increasing VMT

Increasing levels of VMT have direct and indirect effects on the economy, environment, and public safety. Increasing VMT might not only put more stress on infrastructure, such as roads and bridges, but could also lead to increased congestion. While more economic activity could lead to more travel, increasing VMT could be considered as an indication of better economic conditions.

On the other hand, this increased travel will lead to quicker deterioration of road pavement and bridges, leading to economic costs of repair and reconstruction. In a weak economy, such costly investments would be very difficult.

If a large part of this travel occurs on specific routes at specific times, the result is traffic congestion. It is well-documented that congestion results in economic costs, including lost productive hours, energy consumption, pollution, and poor public health. The Texas Transportation Institute's (TTI's) survey of mobility in 439 urban areas in the United States showed that in 2011, traffic congestion resulted in 2.9 billion gallons of wasted fuel and 5.5 billion hours of lost time stuck in traffic. TTI put the cost of this delay and wasted fuel at \$121 billion in 2011. Therefore, while VMT can be a measure of freedom of movement, it has negative impacts.

An increase in VMT points to other issues too. It could result in higher emission of pollutants as long as the current vehicle technologies continue. This could result in deterioration of human health

and climate change. The use of fossil fuels increases greenhouse gases and transportation is responsible for roughly one-quarter to one-third of those greenhouse gas emissions.

In addition to changes in vehicular technology, changing driving behavior to reduce VMT could reduce these negative impacts. Further, it is documented that increasing per capita VMT can result in increased traffic accidents.

Reducing VMT

As mentioned above, reduction in VMT has a number of benefits. Because increases in VMT can have negative impacts on the environment, emissions, safety, and fuel consumption, it is safe to assume that reducing VMT should reduce these impacts. However, there are different opinions about reduction in VMT. Some people argue that VMT is an indication of economic status of a region and reducing the VMT should not be the focus of public policy. They suggest that policies should aim at reducing congestion rather than VMT.

There is general consensus that a combination of congestion pricing, demand management techniques, targeted capacity addition coupled with pricing (for example, heavy occupancy toll lanes or HOT lanes), alternative modes of transportation, and compact land use policies would represent a reasonable package of policies for addressing congestion in metropolitan areas.

The most widely accepted argument for reducing VMT is its environmental impacts. Because emissions and energy consumption are directly related to the amount of driving, any reduction in VMT will also reduce emissions and energy consumption. In fact, the reduction of VMT is an official goal of U.S. government policy as it is stated in sections of the Clean Air Act, Climate Change Action Plan, Congestion Mitigation Air Quality Improvement Program, and the transportation regulations from the 1990s.

Recently, land development and its influence on driving have received close attention. The proponents of compact development argue that sprawl development causes disproportionately high increases in VMT and environmental destruction. Many of the "smart growth" principles try to bring different types of land uses (primarily residential, commercial, and office uses) together. This is expected to reduce the need for vehicular travel

and encourage biking and walking. This depends not only on closeness of activities but also on a built environment that is comfortable, safe, and reliable.

VMT Charges

There is a long-standing debate in transportation and public policy circles on the merits of charges or fees based on a person's length of driving. Such a VMT-based charge is proposed as an alternative to the fuel taxes as a source of federal transportation funding. More than 75 percent of the current federal highway trust account and a large portion of the state funds come from motor fuel taxes.

Irrespective of fuel tax or VMT charges, any reduction in VMT will result in a reduction of available federal funds. However, with the increasing trend of alternate fuels and more fuel efficient technologies, it is likely that there will be further reduction in the use of gasoline. This could result in a reduction of gas-based tax even if VMT increases.

Thus, VMT-based charges could be a more direct user fee based on actual usage of highways and local roads regardless of the vehicle type. Also, even in a reduced VMT scenario, a congestion-based VMT charge could generate sizable revenue. The VMT, gasoline price, gas tax, and VMT charges behave as a system. Therefore, careful analysis of their relationships and different scenarios is required to arrive at sound public policies.

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See Also: Highway Finance; Smart Growth; Urban Sprawl Versus Compact Development; Vehicle Miles Taxation and Fees.

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Vehicle Ownership Models

The dependence of U.S. households on the automobile to pursue daily activity travel patterns has been the subject of increasing research study in recent years because of the far-reaching impacts of this dependence at multiple societal levels.

At the household level, automobile dependency increases the transportation expenses of the household; at a community level, automobile dependency contributes to social stratification and inequity among segments of the population; at a regional level, automobile dependency significantly impacts traffic congestion, environment, health, economic development, infrastructure, land use, and energy consumption. In addition to the overall impacts of vehicle ownership and use on regional quality of life, vehicle ownership and use also plays an important role in travel demand forecasting and transportation policy analysis.

From a travel-demand-forecasting perspective, household vehicle ownership has been found to impact almost all aspects of daily activity travel patterns, including the number of out-of-home activity episodes individuals participate in, the location of out-of-home participations, and the travel mode and time-of-day of out-of-home activity participations.

In addition, households' vehicle ownership and residential location choice are intricately linked. Thus, it is of interest to forecast the impacts of demographic changes in the population (such as aging and rising immigrant population) and vehicle acquisition/maintenance costs (for example, rising fuel prices), among other things, on vehicle ownership and use. From a transportation policy standpoint, a good understanding of the determinants of

vehicle ownership and use (such as the impact of the built environment and acquisition/maintenance costs) can inform the design of proactive land use, economic, and transportation policies to influence household vehicle ownership, which can be used to reduce traffic congestion and air quality problems.

In the past couple of decades, there has been increasing interest in not only examining household vehicle ownership and use but also investigating the composition of the household vehicle ownership by vehicle type. This is because the type of vehicle used for travel has very important implications for transportation planning and operations, as well as fuel consumption and greenhouse gas (GHG) emissions.

This is particularly of interest because of the increasing diversity in the body type of vehicles held by households, mainly attributable to a shift from small passenger cars to large non-passenger cars. In the United States, for example, light-duty trucks (including pickup trucks, minivans, and sport utility vehicles, or SUVs) accounted for just about 20 percent of the fleet 25 years ago they now account for about one-half of all vehicles.

This dramatic shift in the vehicular fleet composition and utilization has implications for roadway capacity, because larger vehicles take up more room on roadways than smaller vehicles. The resulting reduced capacity exacerbates the problem of traffic congestion caused by increasing motorized personal-vehicle use. Further, Environmental Protection Agency (EPA) statistics show that an average van, SUV, or pickup truck produces twice the amount of pollutants emitted by an average passenger car.

Developing Models

Clearly, it is important to accurately predict household vehicle ownership by type, as well as the vehicle miles traveled (VMT) by vehicle type to support critical transportation infrastructure planning and projecting mobile-source emission levels. Further, GHG emissions and fossil-fuel energy dependence are tied closely to vehicle type, leading to a much more concerted effort to develop accurate models of household vehicle holdings (by vehicle type) and use.

Three broad issues in the development of such models relate to (1) the dimensions used to characterize household vehicle type, (2) the determinants of vehicle holdings and use decisions considered in the analysis, and (3) the model structure employed.

Several dimensions can be used to characterize household vehicle type. The most commonly used dimensions of analysis in the existing literature include body type (such as sedan, coupe, pickup truck, SUV, and van), make/model, fuel type, and vehicle acquisition. However, many earlier studies have examined vehicle type using an aggregate vehicle type classification and in the context of the latest vehicle purchased by the household (or the vehicle that the household intends to purchase next), but they have not modeled the entire household vehicle fleet using a fine level of vehicle type classification.

This can be attributed to the computational difficulties in model estimation associated with focusing on the entire fleet of vehicles and/or using several dimensions to characterize vehicle type. Recent advances in econometric estimation procedures and formulations have made it feasible today to do so.

There are several determinants of household vehicle holdings and use decisions, including household and individual demographic characteristics, vehicle attributes, fuel costs, travel costs, and the built environment characteristics (land use and urban form attributes) of the residential neighborhood. Many earlier studies have focused on only a few of these potential determinants.

For instance, some studies exclusively examine the impact of household and individual demographic characteristics, such as household income, household size, number of children in the household, and employment of individuals in the household. Some other studies have identified the impact of vehicle attributes such as purchase price, operating cost, fuel efficiency, vehicle performance, and external dimensions, in addition to demographic characteristics. More recent studies also consider the impact of the driver's personality and travel perceptions on vehicle-type choice, as well as the impact of the built environment on vehicle ownership levels.

Modeling Methodology

In terms of modeling methodology, several types of discrete and discrete-continuous choice models have been used in the literature to model vehicle holdings and use. Most of these studies use standard discrete choice models (that is, multinomial logit, nested logit, or mixed logit) for vehicle ownership and/or vehicle type, and a continuous linear regression model for the vehicle use dimension (if this second dimension is included in the analysis).

These conventional discrete or discrete-continuous models analyze situations in which the decision maker can choose only one alternative from a set of mutually exclusive alternatives. However, this is not representative of the choice situation of multiple-vehicle households, where households own and use multiple types of vehicles simultaneously to satisfy various functional needs of the household.

The analysis of such choice situations requires models that recognize the multiple discreteness in the mix of vehicles owned by the household. Such models have been developed recently and applied to vehicle holdings (by type) and use. But these tend to be estimated using cross-sectional data and represent static models that do not consider the dynamics of household vehicle purchase and disposal decisions.

The application of such static models at different and closely spaced time points can lead to the unrealistic situation of a household holding very different vehicle portfolios between the two time points. However, such static models may be reasonable over longer time periods.

Another formulation that seeks to more consistently reflect the actual household vehicle holdings decision process is the dynamic vehicle transaction approach, in which households decide on disposing, adding, replacing, or maintaining the status quo of their current vehicles over time, as well as the attributes of any new vehicles entering their household vehicle fleet. The dynamic approach is particularly appealing for short-to-medium-term forecasts. However, such transaction models require commitments to collecting longitudinal data over several years. Besides, the theoretical linkage between usage and vehicle type holdings is rather tenuous in most dynamic models to date.

Conclusion

In summary, much remains to be done in developing behavioral models of household vehicle fleet composition and utilization choices—and connecting such choices to activity travel decisions and energy and emissions estimates.

There is a particular need to develop microsimulation models of household vehicle fleet and use and to integrate these with activity-based travel microsimulation models. Doing so will not only provide information on how policy makers may be able to incentivize the ownership and use of

small, fuel-efficient, and alternate-fuel vehicles but also will examine the impacts of policies on activity and travel patterns, GHG emissions, and fuel dependence.

Methodologically speaking, there is a need to use longitudinal data and develop hybrid models that combine the theoretical basis used to motivate static cross-sectional models with the more realistic time-dependent and dynamic process of vehicle holdings behavior.

Another important issue that has not been adequately addressed in the vehicle ownership and utilization literature is that there may be spatial interaction effects in household vehicle ownership and type choice that are both observed and unobserved. Vehicle choices that households make are likely to be influenced by their interactions with neighboring households and the choices that neighboring households make.

If a household observes that many of its neighbors own and drive hybrid electric vehicles, or hears good reviews about such vehicles from neighbors who already own and drive them, then the household may be motivated and influenced to also own and drive a hybrid electric vehicle. Spatial interaction effects may also arise from unobserved attitudinal preferences whereby households with similar lifestyle preferences cluster together in neighborhoods that have built-environment attributes conducive to their lifestyle choices.

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See Also: Activity-Based Models; Automobile Culture; Environmental Impacts; Microsimulation Models; Transportation Studies; Travel by Households; Travel Modeling.

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Visual Pollution

The term *visual pollution* is usually applied to describe the negative effects of man-made structures on people’s perception and enjoyment of the surrounding environment. The concept is subjective, because it depends on one’s aesthetic views, but is often related to aspects such as the disruption of visibility, irregular or incoherent patterns, clutter, juxtaposition of different types of visual elements, and predominance of certain shapes and colors.

The transportation system can be an important source of visual pollution. Large transportation infrastructure can have a disruptive presence in the visual environment, especially in the case of elevated highways and railways. Some features of the design of vehicles can also be regarded as visually unpleasant by some people.

Secondary elements in the transportation infrastructure, such as signs and billboards, can also reduce the aesthetic value of the travel experience for users of the infrastructure. The recognition of the negative impacts of transportation in terms of visual pollution has led to the introduction of laws and public policies to limit or to regulate the quantity and type of elements intruding in the landscape. Despite the recognized effects of visual pollution

on human well-being, there is still relatively little research or methods for its measurement and evaluation.

Elevated highways have a considerable visual effect on people at street level. Because of their large size, they disrupt the perceptions human beings have of the surrounding environment. This is especially true in the case of major junctions, or areas with multiple elevated highways at different heights. Exposure to these effects can be particularly unpleasant in conjunction with exposures to other types of road pollution, such as air pollution and noise. In addition, measures for mitigating pollution (such as noise barriers) may also contribute to visual pollution due to their size, shape, or type of material used.

The scale of the infrastructure is a crucial factor in the aesthetic experience of people at the street level, as it contributes to the monotony of the visible landscape while they are walking. The size of the road and its position at a higher level can also be intimidating for pedestrians, especially when combined with vehicles at fast speed. The presence of transportation infrastructure also affects people’s views from their houses and offices.

Elevated railways have similar visual aspects. The size and position of the infrastructure, combined with the speed of trains and their associated noise and vibration, can be intimidating for the people at the street level and for residents and workers in buildings facing the line.

While most research on visual pollution has focused on the effects of the infrastructure, the traffic on that infrastructure may also have negative effects on the visual environment. In the case of road traffic, important elements include the shape of cars and the reflections from their metallic and curved surfaces and from windshields. These elements can be perceived as alien to the streetscape and, more generally, to the natural and built environments and can be alienating for pedestrians.

This factor may contribute to what some sociologists identify as the unequal relationship of power between car users and pedestrians. When moving at high speeds, vehicles can be intimidating for people at the street level. However, even when parked, cars also can be perceived as a visual nuisance by the pedestrian. Lights from cars can interfere with the pedestrian travel experience and increase pedestrian accident risk when walking along or crossing roads.



The elevated New York City subway system train tracks above this street in Brooklyn, New York, are an example of transportation infrastructure that can have an effect on pedestrians' experience of the surrounding area. Both the size of the railway and the noise or vibration of the trains can be intimidating for people on the sidewalks and for residents and workers in buildings facing the line. Visual and noise pollution created by such infrastructure can contribute to the isolation of some neighborhoods.

Little research has been done on the positive or negative visual effects of other vehicles, such as trains, trams, and motorcycles on human well-being. The analysis of the case of trains and trams may provide interesting results, given the relative popularity of "trainspotting" as a hobby in some countries.

Certain types of road design can also be a source of visual pollution for pedestrians. The expansion of the road infrastructure usually creates traffic islands and other "no-go" areas for pedestrians, which tend to be perceived as visually unpleasant. Traffic furniture also causes visual pollution. In the case of highways, this effect is related to the number and concentration of traffic signs, road markings, and billboards.

Together with other infrastructure, such as telephone and electricity poles, this furniture contributes to an aesthetically unpleasant clutter. Signs

and billboards also disrupt the travel experience of pedestrians, because of their size, the types of material used, and the absence of meaning to them. In the case of railways, large depots and areas with multiple service lines also create an intrusive footprint on the visual environment.

The degree of visual intrusion of transport infrastructure and traffic on pedestrians depends, however, on the context of each area, including its functional use (for example, residential, industrial, recreational, or other), the type of buildings (private houses or high-rise blocks), the presence of other positively pleasant elements, and the climate and other natural characteristics of the area.

The negative visual impact of large transportation infrastructure and traffic on that infrastructure can influence human welfare at many levels. The long-term exposure to unpleasant or intimidating

views can aggravate psychological conditions such as stress and depression. The effect is especially relevant in the cases of residents of buildings facing elevated highways and railroads. The problem may also affect residential satisfaction, because it has been reported in many studies as a factor explaining why people are not happy with the area where they live.

The visual footprint of transport infrastructure also contributes to the dividing of communities and to the isolation of some neighborhoods, with negative resulting effects on community interaction and social cohesion. The visual element is especially important because people need to cross over or under the infrastructure to access nearby communities.

Footbridges place the individuals in close contact with the transport infrastructure and traffic, amplifying the negative aesthetic effects, while underpasses tend to be perceived as ugly and dangerous environments. Visual pollution also affects the levels and quality of mobility of pedestrians and cyclists. Recent research has shown that the negative visual aspects affect the propensity of people to walk, although it is not always possible to disentangle these aspects from the overall negative sensory experience of road traffic.

Visual aspects are also relevant to the users of the transport infrastructure. Because cars move at a fast speed, the aesthetic experience of car travel is associated with the size of the visual field. The presence of elevated highways reduces this visual field and is therefore disruptive. Elevated highways can also cause disorientation for car drivers and passengers, especially around major junctions.

The reduction in visibility caused by signs and billboards also raises safety issues for drivers, as these structures compete for their attention, despite the fact that the mission of some signs is to improve safety by alerting drivers to road conditions.

Measurement

Because of its subjective character, the assessment of visual pollution is fraught with problems, which can prevent their inclusion in transportation project evaluation. The measurement of visual pollution has seen only a few developments, although authors have suggested measurements, such as the degree of intrusion of transportation infrastructure in the visual field.

The evaluation of the economic and social costs of visual pollution is also an under-researched field. A possible, though imperfect, method to estimate this value is to analyze differentials in residential prices and rents in areas with high and low levels of transport-related visual pollution. Because of the difficulties in measurement and evaluation, however, the issue may not be considered a priority in road and urban planners' decisions, especially when compared with more tangible local environmental aspects, such as air pollution and noise.

Nevertheless, aesthetic issues have slowly been included at the level of the design of new transportation infrastructure. In some countries, there are regulations regarding aesthetic elements, while professional bodies and researchers have also produced sets of recommendations to guide the visual arrangement of new transportation infrastructure.

These include, for example, the need to reduce clutter and to minimize the number of large traffic furniture. In the production of these regulations and recommendations, judgments are inevitable, especially regarding the definition of the features that are aesthetically unpleasant.

Recent developments in information technology could potentially contribute to the reduction of street clutter. For example, the use of technology such as the Global Positioning System (GPS) can contribute to the reduction of the number of traffic signs, because it allows information to be passed directly from the traffic control system to drivers.

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See Also: Highway Aesthetics; Highway Landscaping; Light Pollution; Noise Pollution and Cars; Pedestrian-Friendly Design; Road Signage.

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Volatile Organic Compounds

Transportation creates emissions that can have deleterious impacts on public health. Emissions that emanate from motor vehicles or any other device that moves from one location to another are typically known as mobile sources of emissions. These consist not only of on-road vehicles such as cars and trucks but also off-road vehicles such as all-terrain vehicles (ATVs) or snowmobiles, as well as non-road vehicles such as airplanes, locomotives, and certain types of lawn and garden equipment.

One of the most common pollutants is volatile organic compounds, also known as VOCs. According to the U.S. Environmental Protection Agency (EPA), a VOC is any compound of carbon—excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate—that participates in atmospheric photochemical reactions.

In more basic terms, these are all substances that contain carbon and evaporate easily. There are numerous VOCs also emanating from non-mobile sources, or stationary sources, such as oil and gas operations, paints, and cement factories, to name just a few. Some of the more common VOCs include benzene, typically emanating from exhaust fumes from cars in attached garages; formaldehyde, typically used as a disinfectant for biological specimens; and chlorofluorocarbons (CFCs), which were widely used as refrigerants, propellants in aerosol applications, and solvents before being strictly regulated in the late 1970s and beyond.

The emissions just described are known as anthropogenic emissions, because they are basically man-made. There are also VOCs generated from biogenic sources, such as plants and animals. Not counting methane, biological sources emit an estimated 1,150 teragrams (approximately 1.27 billion short tons), of carbon per year in the form of VOCs.

The majority of VOCs are produced by plants, the main compound being isoprene. The remainder are produced by animals, microbes, and fungi such as molds. Of the total VOC concentration in the atmosphere, approximately 72 percent is from biogenic sources and 28 percent from anthropogenic sources. The major anthropogenic VOC emissions

are from on-road vehicles and industrial processes. Although biogenic and stationary sources comprise the majority of sectors producing VOC emissions, mobile-source VOC emissions are the focus of this article. Some VOCs are also considered mobile source air toxics (MSATs), another set of hazardous air pollutants.

VOCs combine with nitrogen oxides (NO_x) under sunlight to create ozone (O_3), one of six criteria pollutants regulated by the EPA under the Clean Air Act. Ozone contributes to what most people experience as “smog” or haze, which occurs most frequently in the summertime but can occur throughout the year in some southern and mountain regions. The highest ozone concentrations usually occur between 2 P.M. and 8 P.M. from May through September.

Most operating vehicles are powered by an internal combustion engine, in which burning fuel creates heat that ultimately propels the wheels supporting the vehicle. VOCs represent one type of emissions that are by-products of this combustion process. These emissions, which occur when the vehicle is operating, are known as tailpipe emissions. VOCs can also escape into the air through fuel evaporation, which can occur even when the vehicle is idling or parked. These emissions are known as evaporative emissions.

Health Impacts

VOCs can have harmful effects by themselves and also in combination with other pollutants. Exposure to air toxins such as VOCs can have cancerous and noncancerous health effects. Noncancerous health effects that can result from exposure include neurological, respiratory, liver, and kidney effects, as well as effects on the immune and reproductive system. People who live or work near major roads or spend a large amount of time in vehicles are likely to have higher exposures and higher risks. Further, people living in homes with attached garages are also likely to be exposed to benzene levels that are higher than average.

As described earlier, in sunlight and heat, VOCs combine with NO_x to create ozone, a criteria pollutant regulated under the Clean Air Act. Ground-level ozone can be harmful to one's health. Even relatively low levels of ozone can cause health effects.

Ground-level ozone can lower one's resistance to diseases such as colds and pneumonia. It can

also damage lung tissue, intensify heart and lung diseases (such as asthma), and cause coughing and throat irritation. Even healthy adults doing heavy exercise or manual labor outdoors may experience the unhealthy effects of ozone. People with lung disease, children, older adults, and people who are active outdoors may be particularly sensitive to high levels of ground-level ozone.

Children are at greatest risk from exposure to ozone because their lungs are still developing, and they are more likely to be active outdoors when ozone levels are high, which increases their exposure. Children are also more likely than adults to have asthma. Ozone can also affect sensitive vegetation and ecosystems, including forests, parks, wildlife refuges, and wilderness areas. In particular, ozone harms sensitive vegetation, including trees and plants during the growing season.

Recent Trends

VOC emissions from all sources decreased 63 percent from 1980 to 2010, and 35 percent from 2000 to 2010. In terms of actual tonnage of pollutants, between 1990 and 2010, total estimated VOC emissions produced nationally decreased by 52 percent, from 23 million tons to 11 million tons.

Looking at the emissions trends in terms of actual quantities, from 1980 to 2010 there has been a decline in total emissions of 177 tons (approximately 66 percent) from all criteria pollutants during that time period. Needless to say, whether it is through cleaner cars, stricter air quality controls, or the shift from a manufacturing to a service-based economy, America is making progress in addressing its overall air quality.

EPA has also instituted stricter regulations on the emissions and controls of MSATs. In February 2007, EPA finalized a rule, known as the Control of Hazardous Air Pollutants from Mobile Sources, to reduce hazardous air pollutants from mobile sources. The rule will limit the benzene content of gasoline and reduce toxic emissions from passenger vehicles and gas cans. EPA estimates that in 2030 this rule will reduce total emissions of VOC by over 1 million tons.

VOC Reduction/Control Strategies

As indicated in statistics cited above, there was a significant decrease in VOCs nationwide from 1980 to 2010. This can be attributed to many federal and

state regulations and control measures that have been implemented within the past several decades. Examples on the mobile side include the vehicle inspection and maintenance (I&M) programs in place in many states, cleaner (reformulated) gasoline, reduced fuel volatility, Stage II Vapor Recovery controls, low-sulfur gasoline, and transportation control measures (TCMs).

Inspection and Maintenance Programs

Vehicle inspection and maintenance programs (I/M) help improve air quality by identifying high-emitting vehicles in need of repair (through visual inspection, emissions testing, and/or the downloading of fault codes from a vehicle's onboard computer) and requiring them to be fixed as a prerequisite to vehicle registration within a nonattainment area. They are mandatory in many ozone nonattainment areas.

Successful implementation of I/M programs has led to a significant decrease in VOC emissions. In Illinois, the I/M program has led to a reduction of 26 tons per day of VOCs in northeastern Illinois, equivalent to the reduction of 650,000 cars per day or 375 medium-sized factories. Illinois's I/M program has also led to a reduction in benzene (among other air toxins) of 260 tons per year.

Reformulated Gasoline (Phase I and Phase II)

Most ozone nonattainment areas now require the use of reformulated gasoline. Reformulated gasoline (RFG) is gasoline blended to burn cleaner and reduce smog-forming and toxic pollutants in the air. Phase I of the reformulated gasoline program made great progress. Between 1995 and 1999, it cut smog-forming pollutant levels by about 17 percent compared to conventional gasoline in communities where 75 million people live and work.

Phase II of the program, which began January 1, 2000, took another step toward cleaner air. It reduces smog-forming pollutants 27 percent more than conventional gasoline. In addition to the federal requirements governing the use of reformulated gasoline, states can also adopt their own, stricter standards.

Reducing Fuel Volatility

Volatility is the property of a fuel that defines its evaporation characteristics. Reducing fuel volatility via the reduction of the Reid vapor pressure (RVP)

is another measure many states have implemented to reduce VOC emissions. At lower RVP values, gasoline evaporates less, thus releasing less VOC into the atmosphere. In certain ozone nonattainment areas, the EPA regulates the vapor pressure of gasoline sold at retail stations during the summer ozone season (June 1 to September 15) to reduce evaporative emissions from gasoline.

Stage II Vapor Recovery

Gasoline-dispensing pump vapor control devices, commonly referred to as Stage II Vapor Recovery Control, are systems that control VOC vapor releases during the refueling of motor vehicles. This process takes the vapors normally emitted directly into the atmosphere when pumping gas and recycles them back into the fuel storage tanks, preventing them from polluting the air. The Stage II system

controls the release of VOC, benzene, and toxics emitted from gasoline.

Low-Sulfur Gasoline

Another measure that has already been implemented and mandated by federal law is the requirement of using low-sulfur fuel. The EPA has issued proposed Tier 3 standards, which would set new vehicle emissions standards and lower the sulfur content in fuel from 30 parts per million (ppm) to 10 ppm, starting in 2017. These proposed standards would reduce both tailpipe and evaporative emissions (including VOCs), from passenger cars, light-duty trucks, medium-duty passenger vehicles, and some heavy-duty vehicles.

The National Association of Clean Air Agencies has estimated that full implementation of the Tier 3 standards and phaseout of the existing Tier



Pedestrians walk through heavy smog seen at street level in Beijing, China, in 2006. Volatile organic compounds (VOCs) combine with nitrogen oxides (NO_x) under sunlight to create ozone (O_3), contributing to smog or haze, which occurs most frequently in the summertime. Even relatively low levels of ozone can be harmful to one's health, causing coughing and throat irritation, damaging lung tissue, and worsening lung diseases such as asthma, as well as affecting the heart, liver, kidney, and brain.

2 standards could reduce VOC emissions 26 percent by 2030, equivalent to an absolute reduction of more than 250,000 tons.

Transportation Control Measures

Transportation control measures (TCMs) are methods of reducing VOC and NO_x emissions by decreasing vehicle miles traveled and improving traffic flow. Typical TCMs for a metropolitan area include a regional ridesharing program, park-and-ride stations, expanded and improved public transit, traffic flow improvements (as in signal synchronization), incentives for bicycles and pedestrians, and employer commute options, as in limiting parking or subsidizing transit for employees. Although these measures do not have as much direct impact on reducing VOC emissions as the other alternatives mentioned, they are relatively inexpensive to implement and have other benefits in addition to reducing VOCs.

Many VOCs have been reduced because of statewide and national regulations. For example, CFCs have been largely curtailed since the United States banned their use in 1978 and the signing of the Montreal Protocol in 1989, which called for the complete elimination of CFCs by 2000.

Conclusion

Ultimately, VOC emission reductions, as with any pollutant, require a combination of strategies, targeting both the on-road, off-road, and stationary sectors. Each of these control strategies will have some impact on reducing VOC emissions. If not known already, this is typically uncovered in the state implementation plan (SIP) development process, when states and regions are in the process of compiling emissions inventories to determine which sectors are contributing the most VOCs.

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See Also: Air Pollution, Automobiles; Air Pollution/Air Quality; Automobile Emissions Controls; Clean Air Act and Amendments; Gasoline, Reformulated; Lead Pollution; Mobile Emissions; Nitrogen Oxides; Particulate Matter; State Implementation Plans; Transportation Control Measures.

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Walking

Walking is a very common type of low-impact aerobic physical activity. Because our ancestors often spent large portions of their days walking in pursuit of resources, our bodies have evolved in the expectation of frequent exercise. Recently, urbanization and specialization of labor have reduced the distances people need to travel to achieve various needs, while simultaneously innovating new means of transportation that do not require physical activity.

Today, walking is still very common, but the average number of steps taken in a day has dropped dramatically. Efforts to employ technology to avoid physical exertion in daily activities have become more and more artful, even as people simultaneously spend considerable effort to attempt to ward off obesity, leading to the common occurrence of people avoiding walking in daily life yet walking on a treadmill at the gym.

People walk for many reasons—for exercise, for transportation, or for the experience itself. Walking can help people maintain a healthy weight, improve balance and coordination, build healthy bones, manage stress and improve emotional well-being, and ward off or manage a range of health problems from diabetes and cardiovascular disease to cognitive decline.

Many people walk with children or animals to supervise them in getting exercise. The U.S. Centers

for Disease Control and Prevention guidelines recommend at least 150 minutes of moderate-intensity exercise, such as brisk walking, each week. However, most U.S. adults do not meet these guidelines.

Especially for short trips, walking is often a great way to get from one location to another within reasonable proximity, in which case walking may be called “active transport.” Taking a stroll can also be very pleasant. Research has found that being near natural scenes and living green environments fosters mental health, stress reduction, and alertness.

Walking can be a form of meditation, including in Zen Buddhist practice. In contrast to most types of mechanized transit, walking allows people to fit into smaller spaces, avoid collisions, and does not require much infrastructure or equipment. Thus, walking can be egalitarian.

Because foot travel allows unplanned deviations and direct physical experience of a place, pedestrians often are more aware of the places they traverse. Whether in urban or rural areas, then, walking can allow interactions such as picking flowers, greeting casual acquaintances, or reading bulletin boards.

These casual interactions might seem unimportant, but researchers believe they help communities build “social capital,” a store of social interactions and expectations that can promote positive action toward shared goals. For instance, bystanders may prevent crime, neighbors may band together to fight against a common problem, and a positive

sense of community may help reduce stress. That is, as more people walk, walking becomes safer for everyone. This “mass effect” is particularly beneficial for those who must walk and thus benefit the most from “eyes on the street.”

Likewise, as more people use public transit, which often involves some walking, too, public transit systems become more financially viable and are able to offer more services. Walking in a place increases knowledge of and emotional investment in the locale, and this sense of community may encourage people not to move out, and to come up with plans to improve the community. The existence of places where many people gather to stroll can be crucial to businesses that rely on “foot traffic”—customers who may not seek out a particular product or service but may be enticed to consume by what they see when they pass by.

Equity Issues

In many places, it is not uncommon to see advantaged locals driving, while disadvantaged residents walk for transport. This image underscores the potential for inequality in transportation, especially given that roads are typically supported by taxes, but car ownership can be an additional price needed to take advantage of roads.

This equity issue becomes even more poignant in areas where public transit is not available and road-sides are not designed to be safe for pedestrians or cyclists because they lack sidewalks, pedestrian overpasses, and car barriers. Not only those who cannot afford vehicles but also children and people with physical limitations experience mobility limitations in car-centered environments.

Adolescents may face additional barriers to walking when their parents’ safety concerns keep them near home, which can be particularly problematic when those safety concerns are unfounded and have the perverse effect of promoting obesity and social isolation.

These aspects of walking provide the potential for a political dimension. Walking takes place in physical space, and this physical space is also social space. Crossing a legal boundary is called “trespassing,” but sometimes walking leads to trespass of merely social boundaries that are nonetheless deeply felt. In this way, walking is often a very different social experience depending on who is walking and where.

Some (often affluent) communities have put in place design features, including fences with gates, that effectively block outsiders from passing. Many racial minorities, people without fixed home addresses, or members of other marginalized groups have experienced harsh words, police action, or violence simply for being in (often public) places from which others wish to exclude them.

Walking can also be an exercise of the power of mass unity, as in street protests, or when employees “walk out” of their workplace in pursuit of shared goals. Another way walking reveals power dynamics is through the experiences of those who are not able to walk the same way others can. Architectural elements such as stairs, curbs, and rough pathways may make navigation very difficult for disabled or elderly people. Many places now have laws—in addition to the federal Americans with Disabilities Act—that require inclusive designs such as ramps.

Actually, the physical environment people live in tends to influence walking behavior for everyone, researchers think. The places people live, work, learn, and play, both those that seem natural and those constructed, have all been changed by human influence. These human habitats are called “the built environment,” a material space reflecting and influencing cultural norms and practices.

Recent Research

A great deal of research in the last 10 years has found that people who live in places with certain design features are more likely to walk, and more frequently. Specifically, there is good evidence that walking for transportation is more common where people live closer together, distance to nonresidential destinations is short, and there are more different types of places nearby (that is, a more diverse land use mix).

There is also some evidence that a more connected street network (such that walking distances are shorter) encourages walking, that parks and open space facilitate walking, and that people avoid walking where they do not feel safe. Many of these ideas have been crystallized into an urban planning paradigm called “new urbanism.” New urbanism encourages urban design standards, such as transit-oriented development (TOD) and neotraditional neighborhood design. Some critics, in fact, view new urbanism as almost “romanticizing” walking.

One challenge in this research agenda is that people who want to walk may choose to live in places where walking is easier. This phenomenon—in which a behavior correlated with a predictor appears to be caused by the predictor but may not be—is called selection (in this case, residential selection). Recent research has focused on determining whether and how the physical features of a place actually directly cause changes in travel behavior or physical activity. This is because the standard of evidence required for changes in government policy ought to be high, particularly since built environment infrastructure is often expensive.

The goal of this policy-oriented research is to suggest how to design better urban planning policies that can promote healthy physical activity, reduce vehicle emissions and fossil fuel consumption, and avert traffic accidents by promoting walking. The goal is to encourage walking in a population, which could help reduce rates of obesity, cardiovascular disease, depression, and other health problems. One irony here is that because walking routes tend to be near roadways, pedestrians can be exposed to higher levels of vehicular and other air pollution while walking than if they were traveling inside cars.

During the 20th century, federal (i.e., the Federal Highway Administration) and state funding was poured into large transportation projects that encouraged construction of highways. Major road construction influenced walking behavior by promoting car ownership and because the roads sometimes served as effective barriers to pedestrians. Some recent initiatives to invest in alternative transportation methods include the Intermodal Surface Transportation Efficiency Act (1991), the Transportation Equity Act for the 21st Century (1998), and the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). These policies have restored incentives and funding for alternative transit, but many still believe that U.S. transportation policy is heavily focused on automotive transit.

Trying to change this trend, some public health advocates have fostered a set of policy initiatives centering on how children get to school. These initiatives attempt to engage parents and schools in creating opportunities for walking and address obstacles to walking, such as fear of crime, traffic danger, and lack of knowledge. For instance, national Walk to

School Days promote walking by making it a community activity and highlighting safe routes.

In the United States, younger adults are rumored to increasingly value an active lifestyle and the ability to walk to work or commercial destinations. This can be a challenge, because U.S. design has been characterized as extremely “automobile-dependent.”

When residential areas are distant from commercial destinations and workplaces, residential lots are large, highways are common, and roads are not very interconnected, this land use pattern has been called “sprawl.” U.S. suburbs and newer cities tend to sprawl.

As the population continues to increase, demand for housing increases. Jobs also shift locations, influencing which cities grow (and shrink). Thus, the future of urban character in the United States and elsewhere is at stake as cities make decisions about how to change and evolve. It is likely that urban form may become more walkable as land values increase, and that walkable areas will rebound in terms of economic valuation, further encouraging demand for walkable areas.

Will the urban form become more walkable? Will Americans take to walking longer distances, and more often? These questions, still unanswered, are important for future population well-being, as well as for the transportation industry.

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See Also: Accessibility and Mobility; Automobile Culture; Complete Streets; Greenways; Livable Streets; Neotraditional Neighborhoods and Transportation Impacts; Pedestrian Travel; Pedestrian-Friendly Design; Rails-to-Trails Programs; Sidewalks; Smart Growth; Street Designs/Patterns; Transit-Oriented Development; Urban Walkways.

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Water Pollution

Water pollution occurs when there is any chemical, biological, or physical change in the quality of a body of water that poses a potential detrimental effect for the plants, animals, and humans that use it.

The main source of water pollution comes from human activities. The damaging activities can be divided into two main sources. The first includes activities that result in the discharge of pollutants at specific locations through pipelines or sewers directly into a body of water, such as the operations of some industrial factories, sewage treatment plants, natural resource mines, and agricultural businesses. The second main source of water pollution is categorized as being nonpoint sources, which are those that cannot be tracked to a single site of discharge. Examples include acid rain, groundwater contamination, and traffic impact.

As transportation activities have increased to support growing demand for passenger and freight mobility, the resulting traffic volumes and ramifications have had negative impacts on water quality in the United States. The Clean Water Act (CWA), established in 1948 and expanded in 1972, outlines the basic structure for regulating discharges of pollutants into U.S. waters and sets quality standards for contaminants in surface waters across the nation. The U.S. Environmental Protection Agency (EPA) is responsible for enforcing the CWA regulations.

Contamination From Transportation

Transportation activities exert significant influence on water conditions and quality. Emissions associated with marine transport represent the most direct source of water quality impact from the transportation sector. The main impact of marine transport operations on water quality derives from dredging, waste, ballast waters, and oil spills.

Dredging involves deepening harbor channels by removing sediment from the floor of the water bed. While the process is critical for creating and maintaining sufficient water depth for shipping operations and port accessibility, it also has a negative outcome for the marine environment. Specifically, dredging stirs up sediment that modifies the water's properties and biological diversity if not subject to decontamination techniques.

Waste generated by the operations of transport vessels at sea or ports can contain high levels of

bacteria that could cause serious environmental and health problems when discharged directly into waters. Furthermore, waste that is not easily biodegradable can linger on the water's surface for long periods of time and impede maritime navigation, especially inland.

Ballast waters are required to control a ship's stability and to account for variances in weight distribution in cargo being transported. Ballast waters acquired in one region may contain non-native species or bacteria that become invasive and destructive when released into a new marine environment. Finally, oil spills from cargo vessel accidents represent one of the most serious problems of pollution from maritime transport activities.

In addition to direct water pollution from maritime transportation activities, there is a tremendous amount of fuel, chemicals, and other hazardous particulates discarded as by-products from airplanes, automobiles, railroads, and port operations every day around the globe. The pollution from sulfuric and nitric acid deposits dispersed into the air, for example, is concentrated by atmospheric conditions and returns to Earth in the form of acid rain.

Acid rains result in increased acidity in still bodies of water such as lakes and wreak havoc on their ecosystem balance. Add to that the dirt, dust, road salt, antifreeze, engine oil, rubber and metal deposits, and other common pollutants found in runoff from roads, bridges, parking lots, and other impermeable transportation surfaces and the upshot is an onslaught of transportation-related pollutants flowing into aquifers, lakes, rivers, streams, and oceans. As a consequence, water chemistry, quality, and habitat are constantly being degraded.

Further contamination of groundwater can be attributed to leaching problems from underground gasoline storage tanks used to support the transportation industry. Similarly, the need to transport millions of gallons of oil each year to serve expanding transportation needs has led to thousands of environmentally damaging marine and surface oil spills each year. Even when there are no accidents during the transport of oil, coal, or other mineral products, the transportation vessels must be cleaned after delivery. That process leads to substantial amounts of pollutants being discharged directly into international waters, causing considerable disruption and potential damage to marine life.



A crewmember stands by while an officer with the U.S. Coast Guard takes samples of ballast water from a ship before it enters the Great Lakes near Montreal, Canada, on June 3, 2008. Ballast water can carry bacteria as well as non-native species, and inspections such as these are mandated to help reduce the introduction of invasive species into the Great Lakes.

The construction and maintenance of transportation infrastructure additionally contributes to water pollution, especially but not exclusively in cases where infrastructure and facilities are erected and operate near aquatic ecosystems.

Storm Water Pollution

Storm water pollution is a serious concern. It results from materials and chemicals—such as used oil, detergent, and dirty water from washing a car—that are swept into storm drains from streets, gutters, parking lots, construction sites, industrial sites, and neighborhoods. Storm water pollution is significant because, unlike the household water that passes down a sink drain or toilet, storm water is left untreated and is carried through municipal water lines and deposited directly into lakes, rivers, streams, bays, or the ocean. Likewise, any material or chemical that is left on the ground can wind up being washed down a gutter and transported into the closest body of water.

Storm water systems were originally designed to swiftly direct rainwater off roadways during heavy storms. However, the same systems also carry pollutants ranging from motor oil to food packaging to construction waste through the streets and into waterways.

Used oil from just one vehicle oil change can contaminate a volume of up to one million gallons of freshwater, making it a significant contributor to storm water pollution. One EPA estimate pegged used oil contamination in the United States as being nearly the equivalent of 17 *ExxonValdez* spills each year.

Even seemingly innocuous materials, such as biodegradable cleansers used to wash one's car, can pose significant problems for fish and other life supported by aquatic habitats if they end up in storm water systems. Contaminated storm water also can be detrimental to human health and recreation. For example, as polluted water makes its

way to the oceans, water quality can be affected to a point where beaches are deemed unhealthy and are closed to human use. Polluted storm water may also carry bacteria and viruses that could cause health problems in humans who swim in it, including earaches, sinus problems, diarrhea, fever, and rashes.

Approaches for Water Cleanup

The best approach to cleaning up contaminated surface water is to prevent additional discharges from contaminated sources. By stemming further damage, the water's natural biological, chemical, and physical processes may be able to break down and eliminate the existing contamination.

In bodies of water where natural processes are insufficient to dissolve the contaminants, other cleanup approaches, such as manual mixing and aeration, may be needed. Contaminated sediments typically contain persistent contaminants that are difficult to resolve and may require removal by dredging, confinement by covering, or patience to allow natural processes to eventually cover the sediment or break the contaminants down over time. For contamination that does not integrate with the surface water and instead floats on the surface, which is common in oil spills, the contamination usually can be removed by skimming it from the surface.

The EPA and its state and territorial partners have developed a range of cleanup programs designed to evaluate and, when necessary, execute cleanup of contaminated sites. The cleanup efforts are conducted by the EPA, other federal agencies, state or municipal governments, and/or the parties deemed responsible for the contamination. In cases where oil or hazardous chemicals have contaminated the environment, the EPA has ultimate responsibility for overseeing the investigation and cleanup efforts.

The Superfund cleanup process is initiated when there is a possible hazardous materials contamination. Using the steps outlined in Superfund, the EPA makes a preliminary assessment and site inspection, ranks the site on the Hazardous Ranking Systems National Priorities List, conducts a remedial investigation and feasibility study to understand the nature and extent of contamination, determines which cleanup methods will be used, and creates a remedial design and action plan. Once cleanup is completed, the EPA oversees ongoing operation and maintenance of the polluted site to ensure effectiveness of the remediation effort.

The EPA's Federal Facilities Restoration and Reuse Office works with other agencies to clean up past pollution such as environmental contamination, hazardous and radioactive waste, munitions and explosives, and toxic substances. Similarly, the EPA's Brownfields and Land Revitalization efforts balance the protection of human health and the environment with needs for redevelopment.

The federal Underground Storage Tank (UST) Cleanup program addresses UST leakages, which seep into the soil and contaminate groundwater used for drinking and surface water used for transportation and other human activities. The EPA also works to prepare for and respond to oil spills affecting the country's inland waterways through its Spill Prevention Control and Countermeasure program (SPCC). The agency indicates that the program has helped reduce the number of oil spills to less than 1 percent of the total volume of oil handled annually.

Enforcement for oil cleanups is provided under the Oil Pollution and Clean Water Acts. Regulatory enforcement encompasses administrative and judicial penalty actions for oil spills, SPCC program violations, and other regulatory requirements.

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See Also: Air Pollution/Air Quality; Air Pollution, Automobiles; Dredging; Environmental Impacts; Environmental Protection Agency; Harbors, Environmental Issues of; National Environmental Policy Act; Ships.

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Welfare Reform

When Bill Clinton ran for president in 1992, one of his campaign pledges was to change the nature of welfare. He proposed reform in 1994 but it was defeated in Congress. In 1996, Republicans put forth a proposal that was passed and signed into law by President Clinton.

That welfare reform act was the Personal Responsibility and Work Opportunity Reconciliation Act of 1996. The aim of the legislation was to move people from a dependence on welfare to working. People were limited as to the time they could receive welfare benefits.

States were given the funds and responsibility for moving people into the workforce. Among the many barriers to people being able to join the workforce was the issue of transportation. Many of those moving from welfare to jobs were faced with the challenge of being able to get reliable transportation to and from their work sites.

Often fathers and mothers had the additional transportation challenge of dropping children off at a child care facility on the way to work and then picking the children up on the way home. The federal government encouraged states to work toward providing transportation alternatives for those in need. States were allowed to use funds provided by the federal government to develop plans and to provide transportation for those transitioning into the job force.

The welfare reform legislation of 1996 created a program titled Temporary Assistance for Needy Families (TANF). This program replaced the Aid to Families with Dependent Children (AFDC) program that had provided welfare payments to families with children. The new program provided for TANF block grants to be made to states, which would have control over the expenditure of those funds within general guidelines.

Some funds were also made available to local government organizations, Indian tribes, and certain other organizations that were tasked with helping move welfare recipients into the workforce. The block grants were for the purpose of providing for individuals as they moved away from welfare and to employment.

The federal legislation provided that individuals could receive payments for only 24 months at a time and that an individual could only receive TANF

payments for 60 months during his or her lifetime. Some states provided for even shorter maximum payment periods. To receive TANF funds, individuals had to go to work, be looking for work, or be preparing for work.

States were encouraged to move individuals to the workforce through target goals set by the federal government. The federal goal was that 50 percent of single-parent family recipients receiving TANF benefits should be involved in work activities. Work activities would include, among other activities, subsidized or unsubsidized work, some educational activities, approved community service involvement, and job searching.

Not all work-related activities were equal. For instance, searching for a job could count for only short periods of time. Among TANF benefits to individuals were direct payments, help with child-care expenses, and help with the expenses for transportation related to work. TANF benefits were a part of the safety net that provided for those in most desperate financial need.

The work requirement is almost supreme in the welfare-to-work system administered primarily by states. There are a number of significant barriers that welfare beneficiaries must overcome if they are to go to work. Among these barriers are lack of education, young children to take care of, lack of role models with good jobs, a poor economy, lack of jobs, lack of job skills and work experience, poor health, substance abuse, domestic abuse, and lack of understanding of workplace practices that are necessary to keep a job. An example of the latter factor is lack of understanding of the need for punctuality. Another major factor is the inability to get to the work site due to lack of transportation.

Transportation

As opposed to the general population, a higher percentage of welfare recipients do not own cars. This lack of independence in transportation contributes to the difficulty of being able to get to a work site in a reasonable length of time. Even with employment, low-income workers may not be able to afford a vehicle and the costs of fuel, insurance, upkeep, taxes, and fees that are inherent in ownership.

Where public transportation is available, the disadvantage is not as severe, but there can still be problems. A significant percentage of welfare recipients live in the central core of cities, but jobs have

often moved from this part of the city to the suburban parts of the metropolitan area. Public transportation is often not particularly reliable in providing dependable transit to the suburbs from the cities, known as reverse commuting. This is especially true when there is no regional transit system and when one must transfer from one system to another. This can add expense and time to the trip to and from work in the suburbs.

Those living in rural areas may face the need to travel nearer to cities to find work because of the paucity of jobs in less densely populated environs. Public transit is seldom available in these rural areas.

Even the cost of good public transit—where it is available—can be prohibitive for someone who is living on the financial edge. The need for help with transportation is largely dependent on how accessible jobs are from the neighborhood where the welfare recipient lives. Also, welfare recipients are likely to get hired in entry-level jobs requiring night and weekend hours when public transit is even more difficult to access. Those in need, maybe for the first time, of public transportation services may not yet have the skills for interpreting bus schedules and routes, especially if transfers are needed.

Transportation Aid

The Transportation Equity Act for the 21st Century (TEA-21), enacted in 1998, was comprehensive federal legislation dealing with a wide variety of transportation needs in the country. It impacted the welfare-to-work transportation issue by creating the Job Access and Reverse Commute (JARC) Grants program. This was a four-year program funded initially through 2003.

The program's purpose was to make grants primarily for mass transit initiatives designed to provide transportation for welfare recipients to and from their work. The focus was also on the development of transportation opportunities to suburban work sites for those who lived in cities, rural areas, and the suburbs. TEA-21 also enabled states to place welfare recipients in training toward employment as skilled highway construction workers. This training was accompanied by support programs that would lead to a greater likelihood of long-term employment, including help with child care expenses and work transportation.

The process of providing transportation aid to low-income individuals who are seeking to move

from welfare to work is complex, and agents in a wide variety of roles must work together if workable solutions are to be found. It is important to note that there is no one solution to the transportation needs of individuals in diverse settings and with diverse backgrounds.

Three separate groups that must absolutely work in tandem are organizations, public or private, providing transportation services; social service providers, especially those dealing with TANF benefits and services; and employers and those working to provide jobs.

Transportation providers are familiar with the issues of providing transit but may not have great familiarity with TANF requirements or with the job situations that those returning to the force face. Each group has its special set of responsibilities. This can lead to a difficult working relationship with the other entities.

The transit company, for example, may not like being told that additional services are needed. Employment entities may not like suggestions that they should provide transportation late at night for their employees who have no cars and are unable to use public transportation. Social service entities may often not like the demands made on them to provide additional funds to develop additional avenues of public or private transit. All this requires a collaborative planning process. The federal government has encouraged the various entities to work closely together for the benefit of those in need of transportation.

Collaborative planning and the work of individual partners in the process have resulted in a great variety of solutions to the transportation needs of former welfare recipients. Not every one of these will work in every setting. There are many variables that can make one plan work better than another in any particular setting.

One solution that has been implemented has been modifying bus routes and schedules to meet the schedules and work sites of those entering the workforce. Another tool has been the use of shuttles or other ways to provide services that may be impractical for a large public bus to provide. These shuttles could be coordinated by various entities interested in providing help, including public transit agencies, faith-based groups, or employers.

Special late-night services have been developed in some locations. Some groups have brought in

a coordinator to help provide for transportation needs. These individuals may work with a variety of transportation formats to provide a customized plan for recipients with various needs.

Carpooling and ridesharing have been encouraged in some settings. A number of plans have been developed to get automobiles into the hands of those needing transportation. A variety of approaches have been used. Sometimes, recipients are sold a car by the social service agency and payments made to the agency go into a pool to be used to replace the cars.

The automobiles are often obtained from government surpluses. Funds have been used to enable former recipients to set up their own transportation companies that provide rides for people moving into the workforce. Subsidies have also been provided to riders to help them pay for public transit fares. There have been additional plans that provided rides for the children of workers to their child care centers.

Information is also provided to riders so that they can understand the transportation system. This includes multilingual materials. All planning should continue to address unmet needs. As people move, as jobs locations shift, and as population centers migrate, there will be a continued need to address transportation needs of those transitioning into the job force.

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See Also: Commuting; Employment Location; Jitneys; Job Access and Reverse Commuting Program; Reverse Commuting; Social Equity and Discrimination in Transportation; Transportation and the Disadvantaged.

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Wildlife Crossings and Barriers

As road construction continues to increase around the world, automobiles are frequently placed in competition with wildlife that historically has occupied or migrated through regions now crossed by roads. This endangers not only the wildlife but also humans. For instance, automobile collisions with large animals may result in injuries or fatalities to the automobile's occupants, not to mention damage to the automobile itself. Construction of underpasses and overpasses for the use of wildlife, referred to collectively as wildlife crossings, is one approach used by transportation ecologists (also called road ecologists) to help solve this problem. However, because the construction of wildlife crossings adds to the cost of road construction, transportation ecologists are concerned not only with establishing the effectiveness of this approach, but also with finding the best ways to build crossings in terms of siting, design, and other aspects.

Background

The practice of constructing wildlife crossings to mitigate the harm caused by road construction is fairly recent in the history of transportation; the first wildlife crossing, an underpass for black bears, was built in 1955 in Florida. The first European wildlife crossing was built in 1974 in the Netherlands; it was a tunnel constructed for badgers. In 1982, Canada built its first wildlife crossing, the Trans-Canada Highway wildlife underpass in Banff National Park, consisting of about 20 underpasses and overpasses, intended for use by many species including bears, wolves, moose, and elk.

The Intermodal Surface Transportation Efficiency Act (ISTEA), a U.S. federal law passed in 1991, included funds for preventing damage to wildlife habitat and thus encouraged construction of wildlife crossings. Today, the longest wildlife overpass in the world is the *Natuurbrug Zanderij Crailoo*; over half a mile (800 meters) long and 54 yards (50 meters) wide, it is located in the Netherlands, which has over other 600 wildlife crossings as well.

Despite this progress, the interaction of humans and wildlife on roads continues to pose a threat to both. According to the Federal Highway



This fencing under construction in April 2012 was part of a new wildlife barrier design intended to direct deer away from unsafe crossings of U.S. Route 97 in central Oregon.

Administration, in the United States alone, millions of vertebrates are killed annually through vehicle collisions, and over 200 motorists die each year in vehicle-animal collisions, with thousands more injured.

Loss of habitat also poses a severe threat to some types of wildlife: for instance, the grizzly bear now occupies less than 2 percent of its former range, and the red-legged frog is no longer found in 99 percent of its former habitat in Canada. A third problem is habitat fragmentation as wildlife populations are divided into smaller, isolated units, increasing their susceptibility to inbreeding and genetic defects, as well as increasing the probability of their extinction from natural causes.

Effectiveness

Researchers studied the effectiveness of wildlife underpasses and fencing to protect white-tailed deer after construction of a 15-mile (24.1 kilometer [km]), four-lane divided highway through forested

and agricultural areas in rural North Carolina. Three wildlife underpasses combined with fencing were included in the road's construction, with the fencing used to guide the deer to the underpasses.

Data was collected from a 10.7-mile (17.3 km) segment of this new road before and after construction, using two actively triggered camera systems (set up so that the camera recorded an event if an infrared beam was interrupted, as by an animal passing through it) at each underpass site, and also by track analysis, identifying species that crossed an 8-foot (2.5-meter) track pad the width of each underpass.

The combination of fencing and underpasses proved generally effective not only for the white-tailed deer, which were the focus of the project, but for other species as well. An average of 6.7 times more deer per day were observed at each of the monitoring sites after construction of the underpasses as opposed to before, suggesting that the fencing was successfully "herding" them to the underpasses.

Most (93 percent judging by camera recordings, 88 percent by track analysis) of the animals using the crossings were deer, but other species, including raccoons, Virginia opossums, American black bears, bobcats, great blue herons, unidentified snakes, and unidentified turtles were also observed using the underpasses (no species other than deer was recorded at the crossings in the pre-construction phase). Wildlife mortality was lowest in the areas closest to the underpasses, but a surprising number of deer were killed while crossing just past the end of the fencing, suggesting that they followed the fence to its end, but in the direction away from the underpass; for this reason, the authors suggested that fencing should be continuous between underpasses.

Another research group studied factors associated with the use of wildlife crossings along a 16.8-mile (27 km) stretch of State Road 260 in central Arizona. In the studied area, before construction of the crossings, motorists experienced about 36 collisions per year with large wildlife, mainly elk.

Seventeen wildlife crossings (11 underpasses and 6 bridges) were included in a reconstruction project for the road between 2000 and 2010. Researchers used animal-triggered video surveillance systems to record the use of the crossings by wildlife and calculated both the number of approaches (coming into

the area but not using the crossing) and successful crossings, finding that 72.4 percent of approaches resulted in successful crossings.

Many species were recorded using the crossings, including black bears, mountain lions, raccoons, and coyotes, but the most common large ungulates (hoofed mammals) recorded were elk (68 percent) and white-tailed deer (13 percent), so only those species were included in a multiple regression analysis to identify factors associated with crossing use. For elk, in the first year of data collection, season, time of day, crossing structure, and months monitored helped predict a successful crossing, but by the fourth year of the study, only the structure of the crossing was significant.

In addition, the probability of a successful crossing increased over the four years of the study, suggesting that the elk learned the location of the crossings over time. For deer, only crossing structure was significant, and that effect held true over all four years of the study. The authors suggest that crossings should not be placed in areas with frequent human activity, should provide cover at the entrances, and should not be built with walls that harm visibility and provide ledges for predators.

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See Also: Aviation Safety, Wildlife Strikes and; Environmental Impacts; Road Ecology; Tunnels, Safety and Security Issues in.

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Women in Transportation

Women tend to be underrepresented in the transportation industry in most countries, especially in management positions and in some traditionally male-oriented professions. This phenomenon is partly linked to broad economic, social, and cultural factors affecting the full participation of women in the job market, and to barriers restricting their opportunities in technical and operational professions. Women working in the industry may also face challenges not faced by male colleagues, such as discrimination both on the job and outside work.

Public policies have increasingly addressed the issue of women in the sector, given the increased political focus on the provision of equal opportunities for all and the realization that the low participation of women in business organizations leads to efficiency losses. Private companies and professional organizations have also led initiatives to promote gender equality in the industry.

In the United States, according to the Bureau of Labor Statistics, only 15.9 percent of the full-time workforce in transportation and material moving occupations were female in 2012, while in the total labor force of the country, the proportion of women was 47 percent.

The European Foundation for the Improvement of Living and Working Conditions reports values of 25 percent and 30.9 percent for the proportions of women in the transportation and communications sector in western and central/eastern Europe, respectively. In developed countries with a

traditionally low proportion of females in the workforce, such as Japan, and in the developing world, the underrepresentation of women in the industry is even more conspicuous than in the United States and Europe.

As in other sectors of the economy, the underrepresentation of women in transportation is especially noticeable in management positions (15.6 percent in the United States). The proportion of women is also low in technical and operational positions. Only customer service positions show proportions of women similar (or in some countries, slightly higher) than proportions of men. Gender-based segregation is also pronounced in professions traditionally dominated by men.

In the United States, professions in the industry with a very small percentage of women include truck drivers (5.4 percent), railroad conductors (5.6 percent), and aircraft pilots (4.1 percent). In most professions, women are particularly under-represented in older age groups. Statistics in some regions of the world, such as in Europe and Australia, also suggest that the proportion of women in many professions seems to be stagnating during the last decade.

Barriers to Participation

The low participation of women in the transportation industry may be partly explained by broader social issues restricting women's employment prospects. For economic, social, and cultural reasons, women often have more demanding space and time restrictions than men, because they are often responsible for tasks such as child care, elder care, shopping, and domestic chores.

The work-life balance is therefore more difficult to manage for women than for men. The issue is especially relevant in the case of jobs in public transportation, because of a high prevalence of shift and night work. The job security of women is also often at risk before and after childbirth, while the right to maternal leave or child care leave is not universal, even when enshrined in the law.

Barriers are also posed to women at the level of recruiting, because they may be faced with intrusive questions not usually asked men regarding age and marital status, which may be used to discriminate in the selection of job candidates.

Other social and cultural issues may explain women's underrepresentation in some professions in the industry. For example, the gender imbalance

in the case of science and engineering jobs may be linked to the lower proportion of women having the required skills, such as mathematics and physics. This fact is, in turn, explained by the traditionally low proportion of women studying in technical universities.

Other professions, such as bus drivers and conductors, may show a gender imbalance because women are at a higher risk than men in terms of personal safety on the job, especially in night buses.

The representation of women in job advertising may also be biased and lead to gender segregation within the industry, because women are more often portrayed as service providers than as technicians, especially in the case of public transportation. Despite the relevance of these social and cultural factors, there is little research on their specific role in shaping women's career choices in the sector, because they also depend on personal preferences.

As in most sectors of the economy, women working in transportation also tend to be at a disadvantage in terms of average earnings. This pattern is mainly explained by their higher relative concentration in lower-paying jobs and by limitations on the opportunities for promotion. The International Transportation Workers' Federation reports that in most countries, women have lower rates of membership in trade unions, leading to lesser power in voicing their specific views.

Women in the transportation industry may also experience discrimination on the job. Discrimination may start at the level of recruiting, because women can be assessed in terms of physical appearance to a higher degree than men, especially in industries such as aviation or in professions such as customer service.

Isolation can also occur because of the minority position of women in a male environment, along with working cultures that may alienate women. The work environment itself may also be hostile because of such factors as the need to wear uniforms that were originally designed for men's bodies, or the lack of female toilets in the workplace. Women may also experience discrimination in the larger society because of stereotypes and prejudices against women employed in some jobs, such as truck drivers.

Efficiency Gains

The gender imbalance in the transportation industry is increasingly relevant in terms of public policy,

in light of recent studies showing that increasing the diversity in a business organization lead to gains in efficiency. For example, a report by Catalyst (a nonprofit organization focusing on women in the business world) shows that the companies in the Fortune 500 group with more female board members tend to show the best performances.

There are also reasons to believe that women can bring unique inputs to organizations in the transportation industry. For example, surveys of practitioners and researchers in the field have shown that women seem to attach more importance than men to the social dimensions of transportation projects, such as the effects in terms of the social inclusion of the populations affected.

Because women are currently underrepresented in managerial positions, women's perspectives on the use of public transportation may also be underrepresented in decisions. As such, an increase in women's share in those positions could have synergic effects in gender equality.

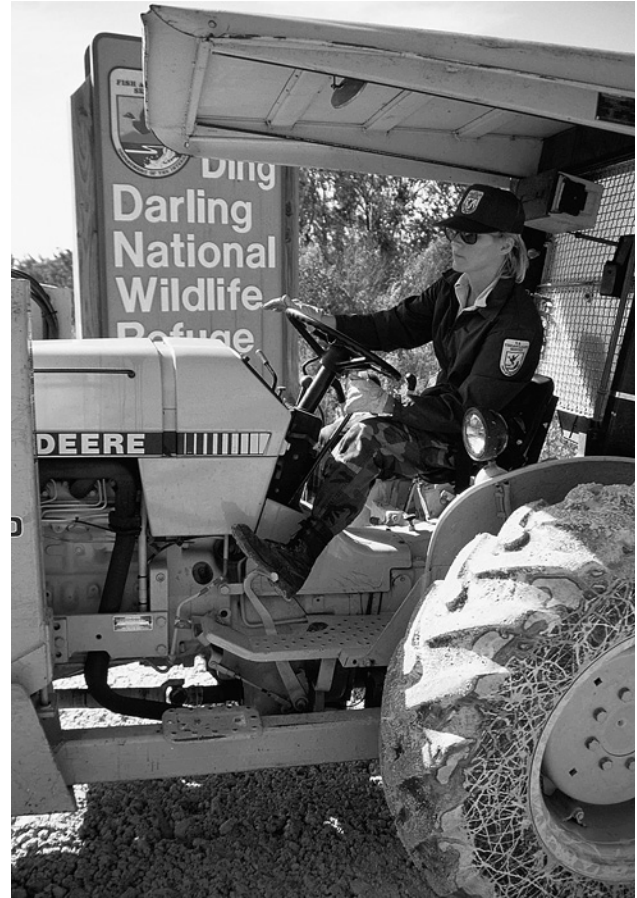
Studies on the role of women in the transportation sector, such as the European Project Wise (Women Employment in Urban Public Transport), have also mentioned the benefits of the communicative qualities of women in administration and customer service.

Legislation

The employment prospects for women in the transportation industry have benefited in recent decades from general equal opportunity employment laws. These policies emphasize the need for equal access to employment and seek to eliminate gender-based discrimination in recruitment and in the workplace.

The issue of establishing mandatory quotas for women is more controversial, and although it has been subject to regular public discussion in several countries, it has rarely been included in equal opportunity laws. Nevertheless, larger companies may set their own targets. Equal opportunity laws also set minimum requirements for the length, timing, and payment of maternity leave.

Despite the advances in this type of legislation around the world, in many developing countries, women are still at a considerable disadvantage in their access to jobs in this sector. This is mainly because transportation firms in these countries operate in a largely informal market, especially in



A U.S. Fish and Wildlife Service worker drives heavy equipment in a national wildlife refuge. While the overall U.S. workforce was 47 percent female in 2012, the full-time transportation and material moving workforce was only 15.9 female.

the case of urban public transport, which tends to be provided by a large number of minibus companies.

In addition, given the informal character of the business and of some of the outer urban areas crossed by these buses, female workers may be at risk of sexual abuse, especially in the cases of night travel. Women are also more exposed than men to harassment from passengers frustrated with poor levels of service.

However, government-led programs have been used to attract women to the transportation industry. In the United States, the Federal Highway Administration (FHWA) and U.S. Department of Transportation (USDOT) provide training, scholarships, and internships to improve the skills of women and other groups underrepresented in the transportation sector. A long-running example

of these projects is the Summer Transportation Internship Program for Diverse Groups, which offers opportunities for field work and work experience for students in transport companies.

Private Sector Initiatives

Initiatives in the private sector have also been important in the quest for increasing the participation of women in the industry, and many of the larger employers now have equal employment policies. Some common measures have the objective of reconciling work hours with women's time restrictions. These include part-time work, flexible working hours, and work-from-home options.

The scope for implementation of these measures is varied. Smaller companies or companies with only a small number of female employees may not have the flexibility required to implement them. The provision of conditions for maternal leave may also be part of the company's equality program, while larger companies may also provide facilities such as kindergartens.

Other initiatives aimed at increasing the attractiveness of transportation jobs for women include job regulations and education regarding sexual harassment between colleagues and, in the case of jobs in services like public transport, a firm stance against harassment from passengers.

Professional organizations have also led an active role in the promotion of professional development for women in the industry by organizing courses and offering scholarships and opportunities for networking. One example is Women in Transportation, an international network of women in the public and private transportation sector that organizes mentoring and leadership training programs.

Workers unions, such as the International Transportation Workers' Federation, have also worked to solve challenges faced by women in the transportation industry, highlighting the specific barriers posed to women in different countries and providing forums for the exchange of experiences.

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See Also: Public Transit Employees and Labor Issues; Social Equity and Discrimination in Transportation; Travel Patterns of Women; Truck Drivers, Labor Issues of; Women's Issues/Gender Issues.

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Women's Issues/ Gender Issues

Among women, there are highly important individual distinctions that depend upon location, income, age, household, elder- and child-care responsibilities, ethnicity, employment status, degree of disability, class, and education. Notwithstanding such variety, there are significant differences between the transport needs, travel behaviors and patterns, and levels of physical access to work, services, and recreation of women compared to men. Gender-based transport differences tend to be more accentuated in developing countries.

A gender analysis of transport systems seeks to reveal these differences in particular contexts. It also seeks to uncover potentially detrimental effects proposed transport programs or projects might have on women and men.

The benefits of this type of analysis include (1) higher economic rates of return on infrastructure investment and higher profitability of mass transport systems; (2) better responsiveness to user demand; (3) lower transaction costs because of system optimization for both genders; and (4) improved access to employment, education, and services for men and women, which ultimately raise productivity and strengthen the household economic base.

Gender issues, including gender equality, gender equity, and gender mainstreaming or gender

integration, have become important in transport, as well as other policy areas.

Gender terms are defined as follows: (1) gender equality refers to the equal rights, responsibilities, and opportunities for women and men; (2) gender equity is the process of being fair to women and men (by including affirmative action, which compensates for historical and social disadvantages); and (3) gender mainstreaming or gender integration is the process of ensuring that gender perspectives are central to all activities, including policy development, research, advocacy/dialogue, legislation, and resource allocation, as well as planning, implementation, and evaluation of transport programs and projects.

Travel Behavior and Patterns

Women, especially in urban areas, tend to take more trips at shorter distances and more varied times than men. More of their trips are associated with their domestic work in maintaining the household, while more of men's trips are work related. Women's trips are costlier in terms of time and money (because they tend to make multiple stops and pay multiple fares).

Because women are more likely to be employed part-time and/or in the informal sector, and to be making social visits to families and friends, their destinations are less concentrated in a few main areas (for example, the central business district). They tend to make more off-peak trips, traveling to more dispersed locations, while most transit service is planned around the typical workday commuting patterns and concentrates on a few major routes.

Women are more likely to "trip chain," which means having multiple stopovers during a trip (for example, on the way to work they might stop at a day care center or a market). Women combine domestic-related trips together to make them more affordable or to link them to a work-related trip. For this reason, women tend to value flexibility over time savings in their travel choices. Frequently, women forgo opportunities to work outside their neighborhoods if they perceive transport services to be unreliable and fares to be expensive.

Men tend to have much more linear origin-destination trips centered on employment. In transport, men tend to value speed, reliability, and road safety. Because income-generating trips are more valued than domestic trips, vehicle use (car, motorcycle,

bicycle, and transit) is higher for men. Also, men generally use motorized modes more than women.

Female trip chaining is not considered in most urban transport system designs. However, there are some exceptions. Metro systems in many east Asian cities cater to busy female commuters by providing grocery and convenience stores, as well as child care, within station buildings. In many cities in south Asia, rickshaws are a popular low-cost, reliable, flexible, door-to-door means of transport, which enables women to travel without being harassed or feeling uncomfortable in overcrowded buses and using inadequate sidewalks.

Travel requirements vary based on household composition (that is, in female-headed households, the woman is responsible for both domestic and income-producing activities and the children bear more responsibility within the household).

Income levels are another factor that affects travel. In both developed and developing countries, gender-based differences are generally less pronounced among the very rich (who can afford private cars) and the very poor. Cultural factors, including religious behavior such as prayer or worship, influence travel behavior as well. While generally women travel more than men, men travel more than women in later stages of life and in Islamic cities.

Public Transport Services

Men and women have different expectations of and experiences with public transport (buses, trams, metros, paratransit, taxis, and trains). As mentioned, women are more likely to travel at off-peak hours; therefore, they prefer a more flexible service.

More often than men, women carry children or shopping bags when utilizing mass transit. Deep steps, onboard ticketing, and lack of room for strollers and shopping carts make it difficult for them to easily enter and exit transit vehicles. To address some of these issues, modern transit systems (including bus systems) offer prepaid, on-level boarding at stations.

In most places, policies exist for passengers to give up their seats to pregnant women or women with young children. Some countries, such as the United Kingdom, employ transport "gender audits" of their public transport systems.

Men have less aversion to overcrowding in public transport vehicles, which for women is a major

security issue because crowding facilitates groping and inappropriate behavior. Also, having generally smaller stature and less physical strength, women are more uncomfortable in overcrowded vehicles, with passengers pushing each other while boarding and alighting.

More often than men, women meet with discrimination in transport services on the part of drivers and ticket collectors (for example, denied boarding or overcharged). Also, women are disinclined to travel in insecure environments, such as taking a bus at night or a taxi alone.

In terms of the unhealthy consequences of transport systems, men are more exposed to air and noise pollution because of the fact that most operators of transit and paratransit vehicles are male.

Private Vehicle Ownership and Use

Typically, men have priority to use a vehicle in a household, and when possible to motorize, while women use the vehicle that is left behind (for example, bicycles when men move to motorcycles, motorcycles when men move to cars). This might be

explained by the fact that a higher value is attached to income-generating trips, and men are more likely to be employed or earn higher income.

Patriarchy is another explanation. Men, with a traditional position of superior power within the household hierarchy, are considered more entitled to appropriate the most efficient means of transport.

Female automobile ownership rates (and also the degree to which women obtain a driver's license) are disproportionately low, even in wealthier countries. (The United States is one of the few countries where this is not the case.) This partly reflects their lack of money to afford to buy vehicles or pay for services. The lack of access to motorized vehicles tends to exacerbate the persistent economic inferiority of women.

Increasingly, women are using bicycles for travel. In some countries (for example, Japan and the Netherlands), the bicycle industry has developed specialized vehicles for women (for example, lightweight, equipped with grocery baskets and/or child seats). On the other hand, in many parts of Africa men are opposed the idea of women cycling.



A commuter stands beside a subway platform sign designating the location of a women-only car available during rush hours in the Rio de Janeiro, Brazil, metro system in January 2013. Women-only subway and train cars, which can provide greater security and protection from harassment, have been introduced in several other countries, including Japan, India, and Mexico.

However, this resistance often decreases if women's economic productivity increases through the use of a bicycle.

Safety and Security

The term *safety* implies road safety, while the term *security* implies perception of danger from crime, violence, and harassment. Although both are matters of concern for both sexes, men tend to be more concerned about safety and women more concerned about security. However, women's safety concerns are higher in relation to nonmotorized than motorized transport (for example, women are less likely to use a bicycle without the provision of bike lanes).

In terms of road safety, more men than women are involved in road crashes. Worldwide, death and injury rates resulting from traffic accidents are four to five times higher for men than women.

In terms of security, women are more vulnerable users of public space and public transport vehicles. Women who carry packages or children, and therefore have their hands full, are targeted and become easy prey of pickpocketing. Because of the fact that they can be overpowered by aggressors (typically men), women's physical safety is threatened as well. On public transport vehicles, women are exposed to verbal harassment by drivers, collectors, or other passengers if wearing short skirts, shorts, or tight clothes. They are also victims of fondling and touching by men, as well as, on rare occasions, physical assault and rape.

Because of security issues, women are often forced to change their transport behavior, thus limiting their transport options. For example, women might decide (1) not to travel at night; (2) not to get out at particular stations, thus lengthening their travel time; (3) to take a longer route home if it is safer; (4) to wear only "appropriate" clothing when walking after dark or using public transportation; (5) to travel in groups, possibly including men; (6) to only board public transport units that are not full; (7) to carry self-defense items; and (8) to stand against a window or at the back of the public transport vehicle.

To deal with security issues affecting women, several cities have instituted gender-targeted policies such as "stops between stops" (Montreal) for women to get off a bus at a between-stops location closer to their destination, "women-only train

carriages" (Tokyo, Mexico City), and "women-only buses" (Dhaka, Bangladesh, a service later found to be unaffordable for most women).

However, general improvements to transport systems, such as good lighting in public transport stations and vehicles, are important enhancers to women's perception of security.

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See Also: Transportation and the Disadvantaged; Travel Patterns of Women; Women in Transportation.

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Work Zone Traffic Control

Work zone traffic safety issues derive from the pervasive number of extensive highway construction and reconstruction projects that are ongoing at any time in every state around the United States. Dangerous conditions lead to high-risk situations because of such varied factors as excessive driving speed, less-than-ideal visual clues, less-than-high alertness, and low levels of comprehension by drivers of the risks involved in work zones.

To meet and answer these challenges, there has been a growing body of research, analysis, and policy development to improve the approaches used by construction management and law enforcement bodies to enhance control of work zone traffic.

Efforts to directly improve work zone traffic control on the roadways include driver education, visual signals, electronic communication, and law enforcement activity.

Driver Education

The plethora of media channels available to improve driver awareness of highway work zone safety issues is an ongoing opportunity as well as a challenge because messages can be diluted if they are not properly targeted and received in an appropriate context by the driving public.

The most appropriate environment for speaking directly to drivers is at the various physical contact points that provide reasonable assurance that individuals are aware of traffic safety and driving behavior information. These contact points include both the physical locations and online manifestations of such places as motor vehicle registry offices, police stations and auxiliary facilities, health care clinics and offices, driver education classes in public and private schools, driver training schools, automobile dealerships, automobile repair shops, and the commercial and institutional headquarters of trucking and bus operators.

Visual Signals

A range of signage motifs and symbols have been tested over the years to alert drivers to construction hazards they are approaching. These continue to be refined. Categories of such signals are diverse. Some are strictly concerned with notifying drivers about approaching lane changes or lane closures. Others focus on explicit speed limit reduction in work zones; many such signs include warning messages about increased fines for speed violations committed in work zones. Still other signs appeal to drivers' empathy with the workers on the road, for example, the "Give 'em a Brake" motif.

Electronic Communication

Increasingly, state highway departments are deploying illuminated signs on roadways that can be updated from centralized and regionalized transportation department control bases. The signs

are positioned as permanent installations on overpasses or purpose-built sign rigs, or, alternately, are positioned as mobile, self-powered units.

In either case, wireless links to transportation authorities permit the display of succinct messages to alert drivers of actual and anticipated work zone traffic situations miles ahead of the work site, giving drivers time to modify their driving behavior on the highway and also to make decisions on alternate routes that may be present.

An adjunct to these standing signs are the mobile modes of personal communications that are available. Highway authority radio dispatches tend to suffer from the limited range of their radio broadcasting, but these projects could improve by uploading their content in podcast form and linking to cell phone and wireless Internet service provider networks.

Some authorities have already deployed mobile apps suitable for a variety of popular mobile device platforms. Real-time video imagery of major interchanges, for example, can be displayed, along with graphic indications or text and tabular displays notifying motorists of work zones in their area.

Law Enforcement Units

Most jurisdictions have come to rely on the physical presence of law enforcement units as the most effective means of assuring better work zone traffic control and safety. However, there is great divergence in the types and intensity of deployment. A typical technique is the positioning of an officer and marked vehicle adjacent to the travel lanes within or upstream of a work zone.

There are choices made by law enforcement officers as to specific operating procedures. Whenever the emphasis is on active identification and citation of traffic law violators, for instance, the officer can operate either overtly in full view of approaching traffic, or adopt a covert strategy from an unmarked vehicle or an out-of-view vehicle position.

If the primary goal is to alert approaching drivers and calm traffic flow in the work zone, the officer and marked vehicle are positioned close to the travel lanes, typically with emergency lights flashing.

Driver Reactions

Research has shown that in order to be motivated to modify their behavior, drivers must perceive a threat of apprehension by law enforcement in order

for the presence of law enforcement in the work zone to be effective.

Driver behavior analysis reveals at least three criteria in the driver's thought process that determine this effect and influence his or her reaction. In some manner or another, the driver must be convinced that there is a significant law enforcement presence. Therefore, any given police unit (1) must be readily visible, (2) must be readily identifiable, and (3) must appear to be prepared for action.

An additional factor in driver perception and motivation to modify behavior is the density of law enforcement units in and around a given work zone. For example, any one police unit, if stationary, is visible to a given driver for only a short time. If the unit is moving with traffic, then it is visible to only a limited number of drivers. By increasing the number of units on hand, more drivers will see a police unit, and will see one or more for a longer period of time. The multiplying effect of law enforcement unit density can be quite significant when it comes to affecting driver behavior in and around a work zone.

A stationary enforcement vehicle and officer will tend to create a greater speed reduction than circulating patrols—but this effect will be localized. Specifically, speeds will be reduced from just before passing the unit to approximately one mile beyond where the unit is located. Therefore, a short distance, for example, approximately 1,000 feet upstream of where the speed reduction is most needed, would be a good position for the law enforcement unit.

On average, speed reductions on high-speed roadways tend to be in the five- to seven-miles per hour (mph) range. Depending on configuration of the road and other factors, however, there can be as much as a 14 mph speed reduction.

Additional Options

According to the National Cooperative Highway Research Program (NCHRP), some of the most effective variations on law enforcement deployment for work zone traffic control include the following measures:

- Stationing police upstream with flashing lights for a lane closure or full road closure on high-speed roads
- Temporary full highway closure (in one or both directions) by patrol cars to provide safe clearance to construction support

vehicles for installing lane closure barriers and markers

- Rolling roadblocks by patrol cars for the same purpose, or to shift traffic between divided-highway sides
- Secondary positioning of a supplemental patrol unit, typically downstream of the work zone, with radar support, to actively interdict and issue citations for traffic speed offenders

These measures, used separately and in conjunction, have been shown to effectively increase the credibility of work zone traffic control efforts in the perception of the driving public.

The NCHRP also has done extensive work in calculating the costs involved in deploying law enforcement officers and vehicles in support of and to direct work zone traffic control. This work has included such variables as overtime pay—and drop-off in effectiveness of personnel—for night deployments.

NCHRP analysis has examined a variety of funding mechanisms and channels for local and state transportation departments to consider. These include program-wide funding, project-by-project funding, and tapping revenues generated from citations issued in work zones.

Just as the nature and intensity of work zone traffic control modes themselves vary, the advantages and disadvantages of these three main funding approaches are applied in a patchwork manner across the country. Some aspects require special state legislative approval (for example, the use of work zone citation revenue to defray work zone enforcement). Other aspects are more administration-heavy, thus sapping a large portion of the funds they are meant to generate or acquire. It seems likely this range of options, rather than any one universal template, will remain the state of enforcement and revenue methodology for some time to come.

Automated Adaptations

Transportation departments in a small number of states now utilize some form of automated or semi-automated speed enforcement technology, which has shown promise as a very cost-effective manner of helping reduce traffic speed in work zones. Deployments of automated units in Maryland, Washington State, and Illinois capture speed data, along with visual evidence of the driver's license

plate, location, and date. In semiautomated deployments, an officer must be present on the scene to verify all data. In other jurisdictions, fully automated systems are permissible.

This tactic has proven effective, in some cases generating substantial revenues to offset other work zone traffic control measures. However, jurisdictions must first invest in the somewhat expensive equipment, supplies, and systems. These initial cost barriers, along with the necessity to amend standing state ordinances, have kept more states from automated or semiautomated system adoption—even those states where similar technology has long been in use to issue citations for red light violations. It is hoped that as the hard costs of such systems are reduced through innovation and defrayed by federal subsidy, the benefits can be harvested by more state transportation departments.

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See Also: Automobile Accidents and Prevention; Highway and Road Safety; Highway Construction and Maintenance; Highway Safety Barriers and Traffic Barriers; Road Surface Marking and Markers.

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World Container Ports

Around 90 percent of all goods traded internationally are transported by ships at some point. Increasing, global demand for raw materials such as oil, metals and food, together with the rapid expansion of manufacturing industries in developing countries such as China and other southeast Asian states, has resulted in rapid growth in the volume of goods transported by sea.

Demand in the United States and Europe for cheap electronics, clothing, cars, and other products from those countries has also contributed to that growth. The top three trade routes for container shipping all originate from Greater China, which includes Hong Kong and Taiwan.

Those routes transport goods to the United States, to Europe, and to "Other" Asia (including all of Asia and Australasia but excluding Greater China, South Korea, and Japan), according to the World Shipping Council (WSC). WSC data also indicate that 10 of the top 20 container ports by volume are located in Greater China. The United Nations estimates indicate that container port throughput grew sixfold in the 20-year period ending in 2010, while WSC statistics show the global container fleet increased from just over 11 million units in 2003 to over 17 million units in 2009.

In order to transport goods in a secure manner and to speed up the whole journey from point of origin to final destination, containers were developed that can be stacked in large numbers on ships and are easily transferrable onto road or rail transport once a ship has arrived at a container port.

The development of shipping containers in the mid-1950s and the subsequent growth in container ports have played a key role in the development of intermodal logistics networks, or global supply chains, which link maritime and land distribution of goods. It has also contributed to a move away from bulk cargo ships that transport only a single cargo type, often requiring a significant amount of time (potentially weeks) and high levels of manpower to be fully unloaded and then reloaded for the return voyage.

In contrast, today's containers can be offloaded by a single individual using a cargo crane or gantry in a very short period of time. Those containers can be immediately loaded for transport away from the port or stored safely within a secure area,

and ships can be quickly reloaded for their next journey.

Containerization has also led to more efficient use of the available space on ships, because multiple cargoes belonging to many different companies can be shipped at the same time. Containers can be used to transport cargo from a number of different sources in a single container, with that cargo only being separated upon arrival at a distribution hub in a destination country.

The increasing use of shipping containers has also led to increases in vessel size, with some ships being capable of carrying more than 16,000 containers on board, with the result that volumes of cargo previously transported by several ships can now be transported in a single voyage. This has also contributed to the need for larger ports and dock-side facilities.

Container Ports

Container ports are maritime (sea) ports where containers arriving by ships can be unloaded for onward transport by road, rail, and inland waterways, or vice versa. Upon arrival in port, containers are offloaded using cargo cranes or gantries and may be either immediately transferred for the next part of their journey or stored in a container terminal.

A container terminal is an area designated for the storage of cargo in containers and is normally accessible by truck, rail, or sea. Full containers can be picked up, dropped off, maintained, or stored in that area. Container yards—additional areas for the storage of empty containers—may also be located within the port, although these areas generally do not have direct access to transport links and containers may be left in them for long periods of time.

Industry statistics from the WSC indicate that, in 2011, 10 of the top 20 container ports in the world were located in Greater China, while another five ports were located in southeast Asia, three in Europe, and one each in the United States and the Middle East. That Middle East port is Jebel Ali in Dubai, which, although ranked only ninth in terms of volume of goods transported, is the world's largest port geographically with a land area of 52 square miles (134 square kilometers).

The top 20 ports worldwide are ranked in Table 1, adapted from the World Shipping Council table of the top 50 world container ports.

Table 1 Top 20 world container ports

Rank	Port and Country	Volume (million TEUs*)
1	Shanghai, China	31.74
2	Singapore, Singapore	29.94
3	Hong Kong, China	24.38
4	Shenzhen, China	22.57
5	Busan, South Korea	16.17
6	Ningbo-Zhoushan, China	14.27
7	Guangzhou Harbor, China	14.26
8	Qingdao, China	13.02
9	Jebel Ali, Dubai, UAE	13.01
10	Rotterdam, Netherlands	11.88
11	Tianjin, China	11.59
12	Kaohsiung, Taiwan	9.64
13	Port Kelang, Malaysia	9.60
14	Hamburg, Germany	9.04
15	Antwerp, Belgium	8.66
16	Los Angeles, United States	7.94
17	Keihin Ports, Japan	7.64
18	Tanjung Pelepas, Malaysia	7.50
19	Xiamen, China	6.47
20	Dalian, China	6.40

*20-foot equivalent units.

Source: "Top 50 World Container Ports." World Shipping Council, 2013.

These rankings change on an annual basis, depending on volumes of trade annually, and so U.S. ports such as Long Beach and New York/New Jersey, which were ranked in the United Nations Conference on Trade and Development (UNCTAD) top 20 container terminals in 2010 (18th and 20th, respectively) are 21st and 25th on the WSC list in 2011. The ports ranked 17th and 20th in Table 1 did not appear in the UNCTAD top 20 in 2010. It is estimated that between 48 percent and 55 percent of global container traffic is handled by the top 20 container ports.

Shipping Containers

United Nations' statistics indicate that world container ports handled almost 337 million TEUs (20-foot equivalent units) of shipping containers through container ports in 2004, rising to over 531 million TEUs in 2010.



An aerial view of containers being transferred at a container port in Cape Town, South Africa, in 2008. Of goods traded internationally, about 90 percent travel by ship at some point.

Cargo volume and ship capacity are measured in TEUs, an industry standard reference set by the International Organization for Standardization (ISO) in 1961. This refers to the size of standard metal shipping containers (also known as intermodal containers, ISO containers, or shipping containers). TEUs are generally defined as measuring 20 feet long (6.1 meters) by 8 feet wide and high (2.44 meters), although heights can vary significantly, and are designed to be stacked on top of one another while being transported on ships.

While the length of containers can vary from the standard 20-foot container to as long as 53 feet (16.1 meters), the two most commonly used lengths and those defined as industry standards by the ISO are the TEU and the FEU (40-foot equivalent unit) containers. The latter is double the length of a TEU but is the same width. It is the most frequently used container because it can be loaded onto a semi-tractor-trailer truck for road transport.

Shipping containers, mainly built of steel or aluminum, are designed to be transferrable between ships, trains, and trucks without the need for the cargo to be unloaded at any point prior to its arrival

at its final delivery point. Containers can be fully enclosed or open sided, depending on what is to be transported inside them.

They can also be temperature controlled (known as a reefer container) when used to store fresh food or sensitive goods, to prevent deterioration of the cargo during its transportation. Increasingly, security of containers has been an issue and so special tamper-proof seals and Global Positioning System (GPS) monitoring is used to ensure they arrive at their destination with their contents intact.

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See Also: Container Terminals; Containerization/ Container Shipping; Freight Transport, Intermodal and Multimodal; Harbor and Port Security; Port Facilities; Security, Transportation; Ships.

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Zero-Emission Vehicles

The term *zero-emission vehicle* (ZEV) came into common usage following the introduction of a landmark piece of legislation in California in 1990. The low emission vehicle (LEV) and Clean Fuels regulation was introduced by the California Air Resources Board (CARB) in September 1990.

One of the primary components to come out of the regulation was the zero-emission vehicle (ZEV) mandate. A relatively unknown concept before its introduction, promoting ZEVs through the mandate was seen as a bold policy, which subsequently became a very prominent and also controversial program. The ZEV mandate has come to be considered as a stand-alone policy, while other components of LEV regulation have progressed separately. The air pollution known as smog, experienced in Los Angeles and other large car-dominated cities in California, was the major driver for introducing the legislation. At the time of the regulation's introduction, efforts to alleviate the problems caused by the high numbers of cars on California's roads were primarily focused on delivering incremental improvements to the conventional internal combustion engine. But these were not producing sufficient results. With people driving farther and more often, and with more people opting for sport utility vehicles (SUVs) and light trucks, rather than standard passenger cars, the problems were worsening, not improving.

The ZEV mandate required a significant shift by requiring car companies that sold more than 35,000 vehicles in the state (at the time, this included General Motors, Ford, Chrysler, Toyota, Honda, and Nissan) to start offering products that did not produce criteria-pollutant tailpipe emissions. The actual definition of a ZEV, offered by CARB in 1990, was vehicles having “no evaporative emissions of any regulated pollutant.”

While not explicitly backing a particular technology at the time of the mandate, there were very limited ZEVs in production, or even in development. This meant that the initiative became focused on a particular technology that was the most advanced and capable of meeting the standards at the time—battery-powered electric vehicles.

This focus may have also stemmed in part from the announcement made by General Motors in 1990 that it was going to begin to commercialize electric vehicles, perhaps suggesting that developments would move quicker for this new vehicle technology than for the others. It actually transpired that hybrid electric vehicles (HEV) and biofuels became favored in the years following the introduction of the mandate, but they are not in its scope because they are not considered pure ZEVs.

The ZEV mandate required each of the large auto manufacturers operating in the state to derive 2 percent of their total annual sales from new vehicles between 1998 and 2000 from ZEVs; that 5 percent



One of the world's most successful zero-emission vehicles (ZEVs), the all-electric Nissan LEAF is seen here charging at an exhibition in June 2011. As of September 2013, a total of 83,000 Nissan LEAFs had been sold worldwide. The sixth version of the California ZEV mandate calls for the production of a total of 60,000 ZEVs from 2012 to 2017, and by 2025, the total ZEV fleet in California is expected to increase to around 1.4 million vehicles, with 250,000 produced in 2025 alone.

of new vehicles sold would be ZEVs in 2001 and 2002; and that from 2003 onward, 10 percent of the new car fleet would consist of ZEVs.

Unlike its predecessors, all of which attempted to address air pollution through so-called command and control measures (that is, forcing technological improvements through fining car companies for noncompliance with pollution levels), the Low Emission Vehicle and Clean Fuel regulation established a credit-based system. The premise of this program was that car companies that exceeded the targets in any given model year could accumulate credits, which could be saved and applied to total sales figures in later years or sold to competitors.

As well as minimizing the risks of investing in new, potentially unproven technologies for large manufacturers, the legislation provided a platform on which small and medium enterprises could also operate by specializing in LEV or ZEV models that

could be sold to larger companies unable to meet their targets. It was a most innovative approach at the time of its introduction.

While companies faced fines (mechanisms were in place for CARB to impose fines of up to \$5,000 for each violation on the manufacturer if it was more than a certain number of vehicles in excess of its quota), the premise was that the LEV program and the ZEV mandate were to be credit based to enable flexibility on the part of the manufacturers.

Amendments

From the introduction of the LEV program, CARB organized biennial reviews of the measures, including the ZEV mandate, to monitor progress against the objectives and ensure that the initiatives engaged relevant stakeholders in their evolution. Some intense policy debates played out in the early years, and, over time, it became clear that the

battery-focused technologies were not cost-effective nor were they performing against the air pollution objectives.

Therefore, since their introduction in 1990, the ZEV mandate rules have been altered several times; carmakers have continued to evade the challenge of delivering ZEVs, and, with changing market pressures and political and policy changes at the state and federal level, the mandate has been something of a moving target.

In 1996, CARB decided that because of the slow progress made in the development of ZEVs, the so-called ramp-up years (that is, the 1998 to 2000 and 2001 to 2002 targets) would be eliminated, leaving companies working toward the 10 percent target by 2003. In 2001, additional modifications were made that allowed the 10 percent target to be broken down further.

The large manufacturers were tasked with providing 2 percent pure ZEVs and 6 percent advanced-technology partial ZEVs, also known as PZEVs, which were to be based on technology designed to lead to ZEVs over time. However, in 2002, following a lawsuit, CARB was prohibited from enforcing the 2001 amendments for model years (MYs) 2002 and 2003.

More amendments followed in 2003, at which time litigation was brought to an end. These changes included pushing the implementation back to 2005. Following several years of review and consultation, CARB approved additional modifications to the mandate in 2008 and set about redesigning the program in 2009.

2017 to 2025 ZEV Mandate

The outcome of these processes—Advanced Clean Cars—was approved as a new emissions-control program for the period 2017 to 2025. This has brought the ZEV mandate in line with the national plan for vehicles, addressing both criteria air pollutants and greenhouse gas (GHG) emissions and the developments that had occurred in California relating to GHG emissions.

The 2017 to 2025 ZEV mandate is the sixth-generation package of measures to try to deliver a smog-free car fleet. From 2012 to 2017, the rules require the production of a total of 60,000 ZEVs, split between those manufacturers with the largest annual sales figures—Chrysler, Ford, General Motors, Honda, Nissan, and Toyota. Beginning in

2017, Audi, BMW, Hyundai, Kia, Mazda, Mercedes-Benz, and Volkswagen will all be expected to deliver against the new targets.

By 2025, the total ZEV fleet in California is expected to amount to somewhere around 1.4 million vehicles, with 250,000 produced in 2025 alone. If the rules are fully implemented by 2025, new cars will be 34 percent less GHG-intensive and emit 75 percent less smog-forming air pollutants.

They will not, however, have achieved the initial vision of the ZEV mandate, an increasing number of emissions-free vehicles over time. Indeed, since the first amendments in 1996, credit has been given to technologies that make conventional vehicles cleaner, with the division between pure ZEV and PZEV. Thus, the distinction that made the ZEV mandate unique to other efforts was removed, and ZEV became just another initiative designed to promote cleaner vehicles.

Assessment

As a result, the ZEV mandate has been heavily criticized. The development of hydrogen vehicles has been promoted at the state and federal level at various times since the introduction of the ZEV mandate, but this promising technology also remains on the periphery of the car market, challenged by the prohibitive research and development costs of scaling down the size of the fuel cell needed to produce the hydrogen often cited as the biggest barrier to mass delivery.

Despite its shortcomings and many critics' labeling the program a failure, there are also proponents of the role that the ZEV mandate has played in pushing progress on cleaner vehicles further than would have been achieved without the goal. And the importance of the ZEV mandate to the international vehicle fleet should also not be underestimated—not only because those car companies regulated in the state would have introduced lower-emission technologies to meet the standard into the global marketplace, but also because one in nine cars in America is sold in California. The state is responsible for some 4 percent of all vehicles sold globally, and so developments in California will continue to be an important driver of innovation and research and development as long as the need for cleaner vehicles remains.

There have also been important general lessons learned in California about the influence that

government can have over industry. Though it was an innovative approach, the ZEV mandates' changing goals and focus over the past 20 years have demonstrated that technology-forcing measures are very difficult to deliver and are unlikely to be accepted by industry. Ultimately, they are unlikely to succeed.

Nonetheless, measures that set particular standards and also offer flexibility about how those goals must be met have been proven in California and elsewhere to be favorable mechanisms for encouraging green technology. Although the ZEV mandate is falling short in terms of reducing air pollutants to the extent initially hoped, it has crafted a process through forward thinking that has potential to deliver results over the longer term.

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See Also: Alternative Fuels; Automobile Engines; Electric Vehicles; Green Fuels; Green Transportation; Hybrid Automobiles/Hybrid Electric Vehicles;

Hydrogen Fuel Cells; Low-Emission Vehicles; Mobile Emissions; Sustainable Transportation.

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Glossary of Terms and Acronyms

AADT: Average annual daily traffic, calculated by dividing the total traffic on a segment of highway over a year by the number of days in the year.

AADTT: Average annual daily truck traffic, a measure calculated by dividing the total volume of truck traffic on a segment of highway over the period of a year by the number of days in the year.

AAR: The Association of American Railroads, an industry organization including Amtrak (passenger rail) and the major U.S. freight railroads.

AASHTO: American Association of State Highway and Transportation Officials, a nonprofit association representing departments of transportation and highway departments in U.S. states, Puerto Rico, and Washington, D.C., with the primary purpose of fostering the development of an integrated system of transportation across the country.

AATF: The Airport and Airway Trust Fund, a fund created in 1970 by the federal Airport and Airway Revenue Act; the revenues come from taxes on users of the U.S. air system, including excise taxes on domestic passenger tickets, international passenger arrivals and departures, and cargo waybills and is used to maintain and expand airport facilities.

ABC classification: A method to classify goods (for instance, for inventory control) by splitting them into classes A (highest value), B (middle value), and C (lowest value); typically, A items are about 10 to 20 percent of the total count and 50 to 70 percent of the expected dollar value, the B group about 20 percent of both the count and the dollar value, and C items about 60 to 70 percent of the count and 10 to 30 percent of the value.

AC: Alcohol concentration, the concentration of alcohol in a person's blood (blood alcohol concentration [BAC]) or breath, used as a proxy for the person's level of intoxication and ability to safely operate a vehicle.

Accident: As defined by the U.S. Department of Transportation, an incident involving a moving vehicle, including collisions, derailments, and leaving the roadway, that produces unintended property damage, injury, or death; a collision of a vehicle with a person, if determined to be a suicide, is not classified as an accident.

Accounts payable: Sometimes abbreviated as A/P, the value of goods and services that have been received but have not been paid for.

Accounts receivable: Sometimes abbreviated as A/R, the values of goods and services that have

been shipped or rendered to a customer but for which the customer has not yet paid.

Ad valorem: A Latin phrase meaning *according to value*; an *ad valorem* tax or duty is based on the value of the items in question.

ADA: Americans with Disabilities Act, a 1990 U.S. law prohibiting discrimination based on handicap or disability; certain accommodations must be made in public transportation to facilitate use by persons with handicaps or disabilities.

ADR: A European agreement known by the French name Accord européen relatif au transport international des marchandises dangereuses par route. It took effect in 1968 and was most recently amended in 2011, regulating the road transportation across national boundaries of dangerous goods.

AGVS: Automated guided vehicle system, a method of transporting materials by small carts that are controlled by computers as they move along a guideway.

Air cargo: Cargo (freight) that is shipped by air.

Aircraft accident: As defined by the U.S. Department of Transportation, an occurrence incidental to flight and which causes fatal or serious injury to one or more people or substantial damage to an aircraft incidental to the operation of an aircraft.

Airline Deregulation Act: A 1978 U.S. federal law that eliminated many regulatory functions of the Civil Aeronautics Board; as a result of the act, fares decreased on many popular routes, and the number of people traveling by air in the United States greatly increased; however, prices increased on some less popular routes.

Airplane: As defined by the U.S. Department of Transportation, a vehicle that is heavier than air, driven by an engine, with fixed wings, and that uses the dynamic reaction of air against its wings in order to remain in flight.

Airship: As defined by the U.S. Department of Transportation, a lighter-than-air vehicle that is driven by an engine and can be steered.

Alternative fuels: Fuels used to replace more conventional fuels commonly used in transportation, such as those derived from petroleum. As defined by the U.S. Energy Policy Act of 1992, alternative fuels include alcohols such as methanol, mixtures including at least 85 percent alcohol, compressed natural gas, hydrogen, liquid petroleum gas, electricity, and fuels derived from biological materials.

AMPO: The Association of Metropolitan Planning Organizations, a nonprofit U.S. organization offering its members technical assistance, communications, access to research and training, and other services.

Analysis of alternatives: A method of approaching an issue by looking at how the various components of a system work together and considering the impact, including costs and benefits, of various proposed changes to that system.

Antidumping duty: A duty placed on imported goods to protect domestic industries; it is imposed when an exporter charges less for exported goods than the usual price in their own domestic market (i.e., when the exporter is dumping cheap goods on another country and thus making it difficult for the industry in the receiving country to compete).

APS: Advanced planning and scheduling, a set of techniques used to optimize manufacturing and logistics operations; often APS is used to simulate the outcomes from different scenarios in order to select the best course of action.

Arterial: A road designated to provide high-volume and high-speed travel, primarily for through traffic; generally, arterials are protected by stop signs, traffic lights, and so on, to avoid the necessity of frequent stops by drivers on the arterial.

ASN: Advanced shipping notice, information sent to a customer about a shipment that has been sent, including the contents of the shipments, and possibly information such as the expected time of arrival and the carrier used.

Asphalt: A sticky petroleum product used in road construction, particularly as asphalt concrete; a

combination of asphalt with other materials such as sand or gravel.

AST&L: The American Society for Transportation and Logistics, an organization founded in 1946 for people working in the logistics and transportation professions and that began offering a certification program in 1948.

ATA: The American Trucking Associations, an organization founded in 1933 to represent the U.S. trucking industry; it was created by the merger of the American Highway Freight Association and the Federation Trucking Associations of America.

Attainment area: In the context of air pollution, a geographic area that has met specified standards, for example, those of the U.S. Clean Air Act, as opposed to a nonattainment area, which has not met those standards; attainment is calculated separately for each pollutant, so a region can be an attainment area for some pollutants and a nonattainment area for others.

Average passenger trip length: In bus and rail travel, a measure calculated by dividing the number of revenue passenger miles by the number of revenue passengers.

AWB: Air waybill, a bill of lading for goods shipped by air.

AWO: The American Waterways Operators, a trade association for operators of barges, towboats, and tugboats on U.S. inland waterways.

Backhaul: The return trip of a transportation vehicle from its original destination to its point of origin; a backhaul may include a full, partial, or empty load.

Barge: A vehicle for carrying cargo over water, usually on inland waterways; barges may or may not have their own propulsion systems and are usually open topped, although covered barges also exist.

Barrier to entry: Any factor that may make it difficult for competitors to enter a market, such as high cost of equipment that must be purchased before beginning operation.

Basing point pricing: A method of pricing the cost of transportation from a specific location in a zone, even if the shipment does not actually depart from that location.

BCP: Business continuity plan, a contingency plan for a business to continue operating despite disruptions such as a natural disaster or labor unrest.

Bill of lading: A legal document specifying the terms and conditions agreed upon by a shipper (such as a shipping line) and the shipper of goods, describing the goods carried and their destination; the bill of lading accompanies the goods and, when they are delivered, is signed by the receiver to signify that they have been received.

Bonded warehouse: A secure warehouse for storing goods until the appropriate revenue laws are observed, for example, duty is paid on the goods.

Bottleneck: A point in a system in which the speed of forward movement is limited by accidental or imposed constraints, for instance, a stretch of road that suddenly narrows or a point in a manufacturing process where production must be slowed because of the lack of an essential component.

Break bulk: A process in shipping in which a bulk load is separated into smaller individual shipments.

B2B: Business to business, companies who sell goods and services primarily to other businesses rather than directly to customers.

B2C: Business to consumer, companies who sell goods and services directly to consumers.

BTS: Bureau of Transportation Statistics, a U.S. federal bureau established in 1992 by the secretary of transportation, with the charge of collecting and analyzing information about transportation, with a particular focus on intermodal transportation.

Bulk cargo: Dry cargo such as grain or coal that is not packaged.

Bulk carrier: A ship designed to carry large quantities of bulk commodities such as oil, grain, or coal in specialized holds; some are designed to carry multiple bulk products, some only a particular product.

Bullwhip effect: A phenomenon in which a small change in demand results in a large change in supply, for instance, from a product being back-ordered to being held in excess; the bullwhip effect is caused by delays in communication and transportation up and down the supply chain.

Cable railway: A type of rail system in which an operator can attach or release a given car from a continuously moving cable.

CAFE: Corporate Average Fuel Economy Standards, a set of standards established by the U.S. federal government for automobile and truck manufacturers requiring that the fleets produced by each manufacturer meet a composite sales-weighted fuel economy standard.

CAPSTAN: Computer-aided planned stowage and networking, a method developed by Koku-mation AB and the Southern Africa Europe Container Service Ltd. to plan stowage on cargo ships.

Cargo airline: An airline that specializes in shipping air freight as opposed to passengers; examples include DHL and FedEx Express.

Carmack Amendment: In the United States, a 1906 amendment to the Interstate Commerce Act of 1887 that clarified the liability of a carrier if goods are damaged while being shipped across state lines.

Carnet: A customs document that allows someone to bring goods into a country without requiring that duty be paid, with the understanding that the goods will be used in the country and then removed; for instance, a person might be allowed to bring a car into a foreign country for their own transportation needs and would not have to pay duty as long as the person took the car when he or she left.

Carpool: A method of transportation in which several people travel together in a private vehicle on

a prescheduled trip to a prearranged destination, possibly sharing the cost and work of driving.

Cartel: A method of limiting competition in which a group of companies decide to cooperate with each other, for instance, by establishing a common price for their goods or services.

Center of gravity approach: A method of planning a supply chain so that distribution centers are located to minimize transportation costs between manufacturing facilities, distribution centers, and markets.

Certificate of origin: A customs document that specifies the location of origin (e.g., the country) of imported goods.

Charter bus: A bus that has been booked by a group of passengers for their exclusive use for a particular trip and for a preestablished price.

Civil Aeronautics Board (CAB): A U.S. government agency established in 1938 to control the aviation market, including specifying the number and type of planes to fly particular routes and the range of ticket prices; most CAB functions were eliminated in the Airline Deregulation Act of 1978, and the board was eliminated in 1985.

CMAQ: Congestion Mitigation and Air Quality Improvement Program, a U.S. federal program that funds projects intended to help meet air quality standards.

CO: Carbon monoxide, a pollutant gas comprised of one oxygen to one carbon atom; it is colorless, odorless, and highly toxic to human beings and is created as a by-product of incomplete combustion.

CO₂: Carbon dioxide, a gas comprised of two oxygen atoms to one carbon atom and which is colorless and odorless; under high compression, it becomes a liquid.

Coastal carrier: A water carrier (ship) that provides service to coastal ports; in the United States, these would include ports on the Gulf of Mexico and the Atlantic and Pacific oceans.

Combi aircraft: An aircraft designed to carry either cargo or passengers or both at the same time.

Commercial bus: A bus that carries passengers in return for specified fees, whether charter service (prebooked for a particular set of passengers) or regular route service (following a specified route and providing transportation along it to anyone who pays the fare).

Common carrier: A company providing transportation of goods and people to the public, does not discriminate against or provide special services to anyone, and is subject to regulation regarding rates, services, and liability.

Commute: A regular trip made between an individual's home and his or her school or workplace.

Compressed natural gas: Natural gas under high pressure so that it can be used as a fuel for vehicles.

COTD: Complete and on-time delivery; a measure of customer service, COTD signifies delivery of a given order in its entirety on or before the time promised.

Culvert: A pipe or other drain allowing water to flow under a road and possibly allowing the passage of wildlife as well.

Deadhead: Returning a vehicle from its destination to its point of origin without transporting a load during that trip.

DUI: Driving under the influence, a legal designation in the United States describing a person judged to be operating a motor vehicle under the influence of illegal drugs or alcohol.

EIS: Environmental Impact Statement, a type of report mandated in the United States for certain federally funded projects, which must specify the potential adverse effects of the project, including pollution, displacement, or disruption of people or communities, and harm to natural resources.

Elevated railway: A railway that operates on tracks above street level.

Energy efficiency: A measure of how efficiently a product (e.g., a car) produces desired outputs relative to inputs (e.g., miles the car can run per gallon of gasoline used).

Environmentally sensitive area: An area with natural resources whose destruction or degradation could have serious consequences; examples include sources of drinking water and the habitat of declining or unique species.

FAA: The Federal Aviation Administration, a U.S. federal entity now part of the Department of Transportation and charged with ensuring aviation safety while encouraging the development of the aviation system.

FHWA: The Federal Highway Administration, the part of the U.S. Department of Transportation charged with administering the Federal Aid Highway Program and the Federal Lands Highway Program.

Funicular: A type of cable railway used to move cars up and down a steep slope by means of a permanently attached cable and in which the weights of ascending and descending vehicles counterbalance one another.

Gasohol: A blend of gasoline and alcohol.

Grade separation: A method of road construction in which intersecting of roads or railroads occurs at different heights so that the traffic on one does not interfere with the traffic on the other.

Gross vehicle weight rating: In the context of truck transport, the maximum rated capacity of a vehicle, including cargo, the driver, passengers, equipment, and the vehicle itself.

Growth management: The use of regulations and planning in an urban area to limit urban sprawl and promote smart growth.

GVW: Gross vehicle weight, the combined weight of a vehicle and the freight it carries.

HOV lane: High occupancy vehicle lane, also known as a commuter lane; one or more lanes of

a highway reserved (possibly at only certain times) for vehicles carrying more than one passenger.

Infrastructure: Physical structure such as roads, railway lines, and bridges that support transportation and development.

Inland and coastal channels: A designation for waterways in the United States that are usable for commercial navigation, including the Mississippi River System, the Great Lakes, the New York State Barge Canal System, the Atlantic Intracoastal Waterway, and the Gulf Intracoastal Waterway, but excluding waterways in Alaska.

Interstate highway system: In the United States, a designated system of divided, limited-access highways of at least four lanes that connect major cities and industrial areas.

ISTEA: The Intermodal Surface Transportation Efficiency Act, a 1991 U.S. federal law that required the creation of regional and state long-term transportation plans, increased the role of regional planning commissions and the public, and increased highway and transportation funding.

LNG: Liquefied natural gas, natural gas that has been made liquid by being cooled to minus 260 degrees Fahrenheit at atmospheric pressure.

Local street: A street intended to provide access to adjacent properties, as opposed to an arterial.

Logistics: Methods of moving goods in an optimal manner, delivering the right amount of product to the right location at the right time and at the right price.

Maglev: A transportation system using magnetic levitation to guide and propel vehicles that are suspended above the tracks.

Monorail: A rail system based on a single rail rather than the dual rails common to most railroads.

MSA: Metropolitan Statistical Area, a designation used by the U.S. Office of Management and Budget including one or more urban areas and

surrounding territory, all of which form an essentially metropolitan area.

MSATs: Mobile Source Air Toxics, a group of 21 hazardous air pollutants identified by the U.S. Environmental Protection Agency as generated largely by transportation sources such as cars and trucks; examples of MSATs include benzene, acet-aldehyde, and formaldehyde.

NAAQS: National Ambient Air Quality Standards; standards set by the U.S. federal government specifying the allowable concentrations of six pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.

NCHRP: National Cooperative Highway Research Program, a U.S. research, development, and technology transfer program administered by the Transportation Research Board of the National Academy of Sciences.

NEPA: National Environmental Policy Act, a 1969 U.S. federal law requiring that any project requiring federal approval or using federal funding consider the environmental effects of a proposed action and its alternatives.

New urbanism: An approach to planning cities or urban areas so they are compact and favor the use of bicycles, foot travel, and public transportation and in which mixed-use areas combining housing, commercial areas, and recreation areas are common.

NHTSA: The National Highway Traffic Safety Administration, created in the United States in 1972 to reduce the deaths and economic losses from highway automobile crashes and to create mileage standards for vehicles weighing less than 10,000 pounds.

No objection fee: A fee paid by a charter airline to a scheduled airline so that the scheduled airline will not protest operation of a charter flight; such a fee is considered a bribe in some countries but is common practice in others.

NO_x: Nitrogen oxides, such as nitric oxide (NO) and nitrogen dioxide (NO₂), that form a major

component of ozone and are produced during high-temperature combustion.

O₃: Ozone, a pollutant formed by three molecules of oxygen and formed by the combination of nitrogen oxides and volatile organic compounds in the presence of sunlight.

ODS: Operating differential subsidy, an amount paid by the U.S. federal government to American flag-carrier ships to help offset the higher operating costs of U.S. as opposed to foreign vessels.

Particulate matter: Pollutants consisting of solid particles and liquid droplets that can be suspended in the air and inhaled; coarse particulate matter is in the range of 10 to 2.5 microns in diameter, while fine particulate matter is less than 2.5 microns in diameter.

Port marks: Letters, numbers, and geometric symbols followed by the name of the port of destination that are placed on export shipments.

Reformulated gasoline: Gasoline designed to reduce pollutants generated as a by-product of combustion, such as including oxygenates and lowering the content of heavy hydrocarbons, olefins, and volatile components.

Riprap: Rock or concrete rubble used to protect shorelines, pilings, abutments, and so on from water erosion.

Semi: Also known as a semi-trailer, a truck trailer without a front axle and which is moved by being coupled to a road tractor.

Shared roadway: An automobile road with a marked bicycle route but without any physical separation of bicycles and automobiles.

Shipper carriers: Companies that own their own vehicle fleets to ship their goods; this is a common arrangement for groceries and big box retail stores.

Shipping conference: An agreement among multiple shipping companies to charge common rates and provide common terms to provide passenger or cargo service over specified routes.

Shipping lane: A mapped route on the ocean used by commercial ships to avoid hazardous areas.

Shipping manifest: A document that lists all the items contained in a shipment, along with the end destination of each and the total weight.

Smart growth: In urban development, a type of growth characterized by efficient land use, mixed-use development integrating housing, commercial development, and recreation, while at the same time preserving open spaces and natural areas; preservation of existing communities is often a consideration also.

Straphangers: Also known as NYPIRG Straphangers, a group founded in 1979 to represent the interests of people using the New York City subway system.

Streetcar: As defined by the U.S. Department of Transportation, a lightweight passenger railcar operating on fixed rails; streetcars may or may not have the right-of-way at intersections and may or may not be separated from other traffic.

Supply chain: The entirety of a manufacturing process, from the acquisition of raw materials to the delivery of finished products, including all the interchanges of materials and information required along the way.

Tanker: A ship designed to carry liquid bulk cargo such as oil.

Tare weight: The weight of an empty shipping container or vehicle.

Third party logistics provider: A company that provides logistics services for other companies, such as transportation, warehousing, and freight forwarding; sometimes abbreviated as 3PL.

Through bill of lading: A bill of lading that covers goods over a journey from origin to destination, including transfers from one carrier to another.

TOFC: Trailer on a flat car, also known as piggy-back, a method of transporting goods by carrying loaded trailers or railcars on a flatcar.

Ton: A measure of weight; a short ton is 2,000 pounds, a long ton 2,240 pounds, and a metric ton 2,204.68 pounds.

Traffic calming: The use of techniques to limit the speed of automobiles and to create safe and pleasant areas for pedestrians and cyclists; examples include the use of speed bumps, curb extensions, and pedestrian islands.

Transshipment: In international trade, transferring a shipment from one carrier (usually a ship) to another.

Tugboat: A powered vessel that is not used for transporting goods but for towing or pushing ships, barges, and rafts.

ULD: Unit load device, a freight container or pallet.

Underpass: A type of grade separation in which one road passes under a railway or another road.

Urban sprawl: A type of development characterized by low density, by isolation of housing from commercial and residential development, and that favors automobile travel rather than public transportation, walking, or cycling.

Viaduct: A bridge constructed to allow one road to pass over another road or over a railroad or valley.

Waybill: A document used in common carrier freight shipment that contains basic facts about the shipment, including origin, destination, and charges.

Wet lease: Renting an aircraft with the provision that the owner will provide fuel, the crew, and ground support equipment (as opposed to a dry lease, in which none of those things is provided by the owner).

Wind rose: A graphical representation of recorded wind speed and direction over a historical period in a particular location.

York-Antwerp Rules: An international code of rules governing shipping, first established in 1890 and amended in 1924 and 1950.

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Resource Guide

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Europe: Transportation
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Appendix

Appendix A

Central Intelligence Agency, The World Factbook Country Comparisons: Transportation..... 1758

Appendix B

U.S. Department of Transportation Research and Innovative Technology Administration,
Bureau of Transportation Statistics, Freight Transportataion: Global Highlights, 2010 1771

Appendix C

U.S. Department of Energy, Clean Cities Alternative Fuel Price Report, October 2013 1825

Central Intelligence Agency, The World Factbook Country Comparisons: Transportation

Table 1 Country comparison: Airports

This table gives the total number of airports or airfields recognizable from the air. The runway(s) may be paved (concrete or asphalt surfaces) or unpaved (grass, earth, sand, or gravel surfaces) and may include closed or abandoned installations. Airports or airfields that are no longer recognizable (overgrown, no facilities, etc.) are not included. Note that not all airports have accommodations for refueling, maintenance, or air traffic control.

Rank	Country	Airports	Rank	Country	Airports
1	United States	13,513	39	Finland	148
2	Brazil	4,093	40	Nicaragua	147
3	Mexico	1,714	41	Libya	146
4	Canada	1,467	42	Cuba	133
5	Russia	1,218	43	Uruguay	133
6	Argentina	1,138	44	Oman	132
7	Bolivia	855	45	Italy	129
8	Colombia	836	46	Czech Republic	128
9	Paraguay	799	47	Poland	126
10	Indonesia	673	48	New Zealand	123
11	South Africa	566	49	Panama	117
12	Papua New Guinea	561	50	Guyana	117
13	Germany	539	51	Malaysia	114
14	China	507	52	Namibia	112
15	Chile	481	53	Korea, South	111
16	Australia	480	54	Honduras	103
17	France	464	55	Iraq	102
18	United Kingdom	460	56	Thailand	101
19	Venezuela	444	57	Mozambique	98
20	Ecuador	432	58	Turkey	98
21	India	346	59	Iceland	96
22	Iran	319	60	Kazakhstan	96
23	Guatemala	291	61	Norway	95
24	Philippines	247	62	Syria	90
25	Sweden	231	63	Zambia	88
26	Saudi Arabia	214	64	South Sudan	85
27	Congo, Democratic Republic of the	198	65	Egypt	83
28	Kenya	197	66	Madagascar	83
29	Zimbabwe	196	67	Korea, North	82
30	Peru	191	68	Denmark	80
31	Ukraine	187	69	Greece	77
32	Angola	176	70	Sudan	74
33	Japan	175	71	Botswana	74
34	Tanzania	166	72	Croatia	69
35	Costa Rica	161	73	El Salvador	68
36	Algeria	157	74	Bulgaria	68
37	Pakistan	151	75	Belarus	65
38	Spain	150	76	Portugal	64

Table 1 (continued) Country comparison: Airports

Rank	Country	Airports	Rank	Country	Airports
77	Burma	64	123	Jamaica	28
78	Switzerland	63	124	Côte d'Ivoire	27
79	Bahamas, The	61	125	Congo, Republic of the	27
80	Somalia	61	126	Turkmenistan	26
81	Lithuania	61	127	Serbia	26
82	Chad	59	128	New Caledonia	25
83	Yemen	57	129	Mali	25
84	Ethiopia	57	130	Bosnia and Herzegovina	24
85	Suriname	55	131	Tajikistan	24
86	Morocco	55	132	Lesotho	24
87	Nigeria	54	133	Burkina Faso	23
88	French Polynesia	54	134	Antarctica	23
89	Uzbekistan	53	135	Georgia	22
90	Austria	52	136	Senegal	20
91	Afghanistan	52	137	Kiribati	19
92	Belize	47	138	Sri Lanka	19
93	Uganda	47	139	Bangladesh	18
94	Nepal	47	140	Jordan	18
95	Israel	47	141	Estonia	18
96	Vietnam	45	142	Cambodia	16
97	Romania	45	143	Slovenia	16
98	Mongolia	44	144	Guinea	16
99	Gabon	44	145	Cyprus	15
100	United Arab Emirates	43	146	Marshall Islands	15
101	Latvia	42	147	Greenland	15
102	Belgium	41	148	Haiti	14
103	Laos	41	149	Swaziland	14
104	Hungary	41	150	Seychelles	14
105	Ireland	40	151	Eritrea	13
106	Central African Republic	39	152	Djibouti	13
107	Taiwan	37	153	Cook Islands	11
108	Azerbaijan	37	154	Armenia	11
109	Dominican Republic	36	155	Macedonia	10
110	Solomon Islands	36	156	Ghana	10
111	Slovakia	35	157	Cabo Verde	9
112	Cameroon	33	158	Singapore	9
113	Malawi	32	159	Maldives	9
114	Vanuatu	31	160	Lebanon	8
115	Niger	30	161	Guinea-Bissau	8
116	Mauritania	30	162	Togo	8
117	Liberia	29	163	Turks and Caicos Islands	8
118	Tunisia	29	164	Sierra Leone	8
119	Puerto Rico	29	165	Burundi	7
120	Netherlands	29	166	Equatorial Guinea	7
121	Fiji	28	167	Rwanda	7
122	Kyrgyzstan	28	168	Kuwait	7

Table 1 (continued) Country comparison: Airports

Rank	Country	Airports	Rank	Country	Airports
169	Moldova	7	204	Saint Kitts and Nevis	2
170	Falkland Islands (Islas Malvinas)	7	205	Saint Lucia	2
171	Benin	6	206	Sao Tome and Principe	2
172	Micronesia, Federated States of	6	207	Virgin Islands	2
173	Kosovo	6	208	West Bank	2
174	Western Sahara	6	209	Saint Pierre and Miquelon	2
175	Tonga	6	210	Aruba	1
176	Timor-Leste	6	211	Wake Island	1
177	Saint Vincent and the Grenadines	6	212	Bermuda	1
178	Qatar	6	213	Brunei	1
179	Northern Mariana Islands	5	214	Cocos (Keeling) Islands	1
180	Mauritius	5	215	Faroe Islands	1
181	Montenegro	5	216	Gambia, The	1
182	Guam	5	217	Gibraltar	1
183	Albania	4	218	Gaza Strip	1
184	Bahrain	4	219	Isle of Man	1
185	Comoros	4	220	British Indian Ocean Territory	1
186	French Southern and Antarctic Lands	4	221	Jersey	1
187	Samoa	4	222	Jan Mayen	1
188	Svalbard	4	223	Christmas Island	1
189	Trinidad and Tobago	4	224	Macau	1
190	British Virgin Islands	4	225	Montserrat	1
191	Spratly Islands	4	226	Malta	1
192	Antigua and Barbuda	3	227	Niue	1
193	American Samoa	3	228	Norfolk Island	1
194	Palau	3	229	Nauru	1
195	Grenada	3	230	Paracel Islands	1
196	Cayman Islands	3	231	Saint Martin	1
197	Anguilla	2	232	Saint Helena, Ascension, and Tristan da Cunha	1
198	Bhutan	2	233	Sint Maarten	1
199	Dominica	2	234	Saint Barthelemy	1
200	Guernsey	2	235	Tuvalu	1
201	Hong Kong	2	236	Barbados	1
202	Luxembourg	2			
203	Wallis and Futuna	2			

Table 2 Country comparison: Railways

This table states the total route length of the railway network and of its component parts by gauge, which is the measure of the distance between the inner sides of the load-bearing rails. The four typical types of gauges are broad, standard, narrow, and dual. Other gauges are listed under note. Some 60 percent of the world's railways use the standard gauge of 1.4 meters (4.7 feet). Gauges vary by country and sometimes within countries. The choice of gauge during initial construction was mainly in response to local conditions and the intent of the builder. Narrow-gauge railways were cheaper to build and could negotiate sharper curves; broad-gauge railways gave greater stability and permitted higher speeds. Standard-gauge railways were a compromise between narrow and broad gauges.

Rank	Country	Kilometers	Rank	Country	Kilometers
1	United States	224,792	38	Mozambique	4,787
2	Russia	87,157	39	Norway	4,237
3	China	86,000	40	Bulgaria	4,152
4	India	63,974	41	New Zealand	4,128
5	Canada	46,552	42	Thailand	4,071
6	Germany	41,981	43	Congo, Democratic Republic of the	4,007
7	Australia	38,445	44	Algeria	3,973
8	Argentina	36,966	45	Serbia	3,809
9	France	29,640	46	Tanzania	3,689
10	Brazil	28,538	47	Bolivia	3,652
11	Japan	27,182	48	Uzbekistan	3,645
12	Ukraine	21,619	49	Slovakia	3,622
13	Italy	20,255	50	Nigeria	3,505
14	South Africa	20,192	51	Zimbabwe	3,427
15	Poland	19,428	52	Korea, South	3,381
16	Mexico	17,166	53	Portugal	3,319
17	United Kingdom	16,454	54	Ireland	3,237
18	Kazakhstan	15,333	55	Belgium	3,233
19	Spain	15,293	56	Netherlands	3,013
20	Turkey	12,008	57	Turkmenistan	2,980
21	Sweden	11,633	58	Azerbaijan	2,918
22	Romania	10,777	59	Angola	2,764
23	Czech Republic	9,469	60	Croatia	2,722
24	Iran	8,442	61	Denmark	2,667
25	Cuba	8,203	62	Vietnam	2,632
26	Hungary	8,057	63	Namibia	2,626
27	Pakistan	7,791	64	Bangladesh	2,622
28	Chile	7,082	65	Greece	2,548
29	Austria	6,399	66	Iraq	2,370
30	Sudan	5,978	67	Latvia	2,239
31	Finland	5,944	68	Tunisia	2,165
32	Belarus	5,537	69	Zambia	2,157
33	Korea, North	5,242	70	Morocco	2,067
34	Egypt	5,083	71	Kenya	2,066
35	Indonesia	5,042	72	Syria	2,052
36	Burma	5,031	73	Mongolia	1,908
37	Switzerland	4,876	74	Peru	1,907

Table 2 (continued) Country comparison: Railways

Rank	Country	Kilometers	Rank	Country	Kilometers
75	Malaysia	1,849	105	Gabon	649
76	Lithuania	1,767	106	Burkina Faso	622
77	Uruguay	1,641	107	Bosnia and Herzegovina	601
78	Georgia	1,612	108	Fiji	597
79	Taiwan	1,580	109	Mali	593
80	Sri Lanka	1,449	110	Togo	568
81	Saudi Arabia	1,378	111	Jordan	507
82	Cameroon	1,245	112	Kyrgyzstan	470
83	Uganda	1,244	113	Benin	438
84	Slovenia	1,228	114	Kosovo	430
85	Estonia	1,196	115	Liberia	429
86	Moldova	1,190	116	Lebanon	401
87	Guinea	1,185	117	Albania	339
88	Philippines	995	118	Guatemala	332
89	Israel	975	119	Eritrea	306
90	Ecuador	965	120	Swaziland	301
91	Ghana	947	121	El Salvador	283
92	Senegal	906	122	Costa Rica	278
93	Botswana	888	123	Luxembourg	275
94	Congo, Republic of the	886	124	Montenegro	250
95	Colombia	874	125	Dominican Republic	142
96	Armenia	869	126	Djibouti	100
97	Madagascar	854	127	Panama	76
98	Venezuela	806	128	Isle of Man	63
99	Malawi	797	129	Nepal	59
100	Macedonia	699	130	Saint Kitts and Nevis	50
101	Cambodia	690	131	Honduras	44
102	Ethiopia	681	132	Paraguay	36
103	Tajikistan	680	133	Christmas Island	18
104	Côte d'Ivoire	660	134	Liechtenstein	9

Table 3 Country comparison: Roadways

This table gives the total length of the road network.

Rank	Country	Kilometers	Rank	Country	Kilometers
1	United States	6,586,610	44	Korea, South	104,983
2	India	4,689,842	45	Libya	100,024
3	China	4,106,387	46	Kazakhstan	97,418
4	Brazil	1,580,964	47	Zimbabwe	97,267
5	Russia	1,283,387	48	Venezuela	96,155
6	Japan	1,210,251	49	Ireland	96,036
7	Canada	1,042,300	50	New Zealand	94,160
8	France	1,028,446	51	Norway	93,870
9	Australia	823,217	52	Zambia	91,440
10	Spain	683,175	53	Uzbekistan	86,496
11	Germany	645,000	54	Tanzania	86,472
12	Sweden	579,564	55	Belarus	86,392
13	Indonesia	496,607	56	Romania	84,185
14	Italy	487,700	57	Lithuania	84,166
15	Poland	412,035	58	Portugal	82,900
16	United Kingdom	394,428	59	Côte d'Ivoire	81,996
17	Turkey	385,748	60	Bolivia	80,488
18	Mexico	377,660	61	Finland	78,000
19	South Africa	364,131	62	Chile	77,764
20	Pakistan	262,256	63	Uruguay	77,732
21	Argentina	231,374	64	Denmark	73,929
22	Saudi Arabia	221,372	65	Latvia	72,440
23	Philippines	213,151	66	Switzerland	71,464
24	Vietnam	206,633	67	Yemen	71,300
25	Hungary	199,567	68	Syria	69,873
26	Iran	198,866	69	Cuba	60,858
27	Nigeria	193,200	70	Oman	60,240
28	Thailand	180,053	71	Iraq	59,623
29	Ukraine	169,694	72	Turkmenistan	58,592
30	Kenya	160,878	73	Estonia	58,412
31	Belgium	154,012	74	Morocco	58,395
32	Congo, Democratic Republic of the	153,497	75	Azerbaijan	52,942
33	Malaysia	144,403	76	Angola	51,429
34	Colombia	141,374	77	Cameroon	51,350
35	Peru	140,672	78	Mongolia	49,249
36	Netherlands	139,295	79	Ethiopia	44,359
37	Egypt	137,430	80	Guinea	44,348
38	Czech Republic	130,671	81	Serbia	44,248
39	Austria	124,508	82	Namibia	44,138
40	Greece	116,960	83	Slovakia	43,916
41	Sri Lanka	114,093	84	Ecuador	43,670
42	Algeria	113,655	85	Afghanistan	42,150
43	Ghana	109,515	86	Taiwan	41,475

Table 3 (continued) Country comparison: Roadways

Rank	Country	Kilometers	Rank	Country	Kilometers
87	Chad	40,000	133	Mauritania	10,628
88	Cambodia	39,618	134	Liberia	10,600
89	Laos	39,568	135	Qatar	9,830
90	Costa Rica	39,018	136	Moldova	9,352
91	Slovenia	38,985	137	Papua New Guinea	9,349
92	Madagascar	34,476	138	Gabon	9,170
93	Burma	34,377	139	Trinidad and Tobago	8,320
94	Kyrgyzstan	34,000	140	Bhutan	8,050
95	Paraguay	32,059	141	Guyana	7,970
96	Mozambique	30,331	142	Montenegro	7,763
97	Croatia	29,410	143	Armenia	7,705
98	Tajikistan	27,767	144	Jordan	7,203
99	Puerto Rico	26,862	145	Lebanon	6,970
100	Korea, North	25,554	146	Kosovo	6,955
101	Bosnia and Herzegovina	22,926	147	El Salvador	6,918
102	Mali	22,474	148	Kuwait	6,608
103	Jamaica	22,121	149	Timor-Leste	6,040
104	Nicaragua	22,111	150	Lesotho	5,940
105	Somalia	22,100	151	New Caledonia	5,622
106	Bangladesh	21,269	152	Rwanda	4,700
107	Central African Republic	20,278	153	West Bank	4,686
108	Cyprus	20,006	154	Suriname	4,304
109	Uganda	20,000	155	Haiti	4,266
110	Dominican Republic	19,705	156	Bahrain	4,122
111	Bulgaria	19,512	157	United Arab Emirates	4,080
112	Tunisia	19,418	158	Eritrea	4,010
113	Georgia	19,109	159	Gambia, The	3,740
114	Niger	18,949	160	Swaziland	3,594
115	Israel	18,566	161	Guinea-Bissau	3,455
116	Albania	18,000	162	Fiji	3,440
117	Botswana	17,916	163	Singapore	3,425
118	Congo, Republic of the	17,289	164	Malta	3,096
119	Benin	16,000	165	Djibouti	3,065
120	Malawi	15,450	166	Brunei	3,029
121	Burkina Faso	15,272	167	Luxembourg	2,899
122	Panama	15,137	168	Equatorial Guinea	2,880
123	Honduras	14,742	169	Belize	2,870
124	Macedonia	14,038	170	Bahamas, The	2,700
125	Senegal	14,008	171	French Polynesia	2,590
126	Iceland	12,890	172	Samoa	2,337
127	Burundi	12,322	173	Mauritius	2,149
128	Sudan	11,900	174	Hong Kong	2,090
129	Togo	11,652	175	Marshall Islands	2,028
130	Guatemala	11,501	176	Barbados	1,600
131	Sierra Leone	11,300	177	Dominica	1,512
132	Nepal	10,844	178	Solomon Islands	1,390

Table 3 (continued) Country comparison: Roadways

Rank	Country	Kilometers	Rank	Country	Kilometers
179	Cabo Verde	1,350	202	Cook Islands	320
180	Virgin Islands	1,260	203	Andorra	320
181	Saint Lucia	1,210	204	Sao Tome and Principe	320
182	Antigua and Barbuda	1,170	205	San Marino	292
183	Grenada	1,127	206	American Samoa	241
184	Vanuatu	1,070	207	Micronesia, Federated States of	240
185	Guam	1,045	208	British Virgin Islands	200
186	Comoros	880	209	Saint Helena, Ascension, and Tristan da Cunha	198
187	Saint Vincent and the Grenadines	829	210	Anguilla	175
188	Cayman Islands	785	211	Christmas Island	140
189	Tonga	680	212	Turks and Caicos Islands	121
190	Kiribati	670	213	Niue	120
191	Jersey	576	214	Saint Pierre and Miquelon	117
192	Curacao	550	215	Maldives	88
193	Northern Mariana Islands	536	216	Norfolk Island	80
194	Seychelles	508	217	Monaco	77
195	Isle of Man	500	218	Sint Maarten	53
196	Faroe Islands	463	219	Nauru	30
197	Bermuda	447	220	Gibraltar	29
198	Falkland Islands (Islas Malvinas)	440	221	Cocos (Keeling) Islands	22
199	Macau	413	222	Tuvalu	8
200	Saint Kitts and Nevis	383			
201	Liechtenstein	380			

Table 4 Country comparison: Waterways

This table gives the total length of navigable rivers, canals, and other inland bodies of water.

Rank	Country	Kilometers	Rank	Country	Kilometers
1	China	110,000	44	Mali	1,800
2	Russia	102,000	45	Japan	1,770
3	Brazil	50,000	46	Romania	1,731
4	Vietnam	47,130	47	Ukraine	1,672
5	United States	41,009	48	Hungary	1,622
6	Colombia	24,725	49	Gabon	1,600
7	Indonesia	21,579	50	Uruguay	1,600
8	Congo, Democratic Republic of the	15,000	51	Korea, South	1,600
9	India	14,500	52	Norway	1,577
10	Burma	12,800	53	Ecuador	1,500
11	Argentina	11,000	54	Angola	1,300
12	Papua New Guinea	11,000	55	Guinea	1,300
13	Bolivia	10,000	56	Turkmenistan	1,300
14	Peru	8,808	57	Ghana	1,293
15	Nigeria	8,600	58	Switzerland	1,292
16	France	8,501	59	Afghanistan	1,200
17	Bangladesh	8,370	60	Turkey	1,200
18	Finland	8,000	61	Suriname	1,200
19	Germany	7,467	62	Congo, Republic of the	1,120
20	Malaysia	7,200	63	Uzbekistan	1,100
21	Venezuela	7,100	64	Senegal	1,000
22	Netherlands	6,237	65	Spain	1,000
23	Iraq	5,279	66	Guatemala	990
24	Laos	4,600	67	Côte d'Ivoire	980
25	Sudan	4,068	68	Ireland	956
26	Thailand	4,000	69	Syria	900
27	Kazakhstan	4,000	70	Iran	850
28	Poland	3,997	71	Belize	825
29	Cambodia	3,700	72	Sierra Leone	800
30	Egypt	3,500	73	Panama	800
31	Philippines	3,219	74	Croatia	785
32	United Kingdom	3,200	75	Costa Rica	730
33	Paraguay	3,100	76	Malawi	700
34	Mexico	2,900	77	Czech Republic	664
35	Central African Republic	2,800	78	Canada	636
36	Belarus	2,500	79	Kyrgyzstan	600
37	Italy	2,400	80	Madagascar	600
38	Korea, North	2,250	81	Serbia	587
39	Zambia	2,250	82	Mongolia	580
40	Nicaragua	2,220	83	Moldova	558
41	Sweden	2,052	84	Bulgaria	470
42	Belgium	2,043	85	Honduras	465
43	Australia	2,000	86	Mozambique	460

Table 4 (continued) Country comparison: Waterways

Rank	Country	Kilometers	Rank	Country	Kilometers
87	Lithuania	441	98	Fiji	203
88	Denmark	400	99	Tajikistan	200
89	Gambia, The	390	100	Slovakia	172
90	Austria	358	101	Sri Lanka	160
91	Estonia	335	102	Benin	150
92	Guyana	330	103	Togo	50
93	Latvia	300	104	Albania	41
94	Niger	300	105	Luxembourg	37
95	Cuba	240	106	Liechtenstein	28
96	Portugal	210	107	Greece	6
97	Brunei	209	108	Kiribati	5

Table 5 Country comparison: Merchant marine

Merchant marine may be defined as all ships engaged in the carriage of goods; or all commercial vessels (as opposed to all nonmilitary ships), which excludes tugs, fishing vessels, offshore oil rigs, etc.

Total includes the number of ships (1,000 GRT or over), total DWT for those ships, and total GRT for those ships. DWT or dead weight tonnage is the total weight of cargo, plus bunkers, stores, etc., that a ship can carry when immersed to the appropriate load line. GRT or gross register tonnage is a figure obtained by measuring the entire sheltered volume of a ship available for cargo and passengers and converting it to tons on the basis of 100 cubic feet per ton; there is no stable relationship between GRT and DWT.

Ships include barge carriers, bulk cargo ships, cargo ships, chemical tankers, combination bulk carriers, combination ore/oil carriers, container ships, liquefied gas tankers, livestock carriers, multifunctional large-load carriers, petroleum tankers, passenger ships, passenger/cargo ships, railcar carriers, refrigerated cargo ships, roll-on/roll-off cargo ships, short-sea passenger ships, specialized tankers, and vehicle carriers.

Rank	Country	Merchant marine	Rank	Country	Merchant marine
1	Panama	6,413	31	Malaysia	315
2	Liberia	2,771	32	Gibraltar	267
3	China	2,030	33	Belize	247
4	Malta	1,650	34	Sierra Leone	215
5	Hong Kong	1,644	35	Canada	181
6	Singapore	1,599	36	France	162
7	Marshall Islands	1,593	37	Korea, North	158
8	Indonesia	1,340	38	Saint Kitts and Nevis	152
9	Antigua and Barbuda	1,257	39	Comoros	149
10	Bahamas, The	1,160	40	Georgia	142
11	Russia	1,143	41	Bermuda	139
12	Greece	860	42	Sweden	135
13	Cyprus	838	43	Ukraine	134
14	Korea, South	786	44	Spain	132
15	Netherlands	744	45	Moldova	121
16	Japan	684	46	Cayman Islands	116
17	Italy	681	47	Taiwan	112
18	Turkey	629	48	Brazil	109
19	Norway	585	49	Barbados	109
20	Vietnam	579	50	Portugal	109
21	Cambodia	544	51	Finland	97
22	United Kingdom	504	52	Tanzania	94
23	Philippines	446	53	Azerbaijan	90
24	Germany	427	54	Nigeria	89
25	Saint Vincent and the Grenadines	412	55	Honduras	88
26	United States	393	56	Belgium	87
27	Denmark	367	57	Vanuatu	77
28	Thailand	363	58	Kiribati	77
29	India	340	59	Croatia	77
30	Isle of Man	321	60	Iran	76

Table 5 (continued) Country comparison: Merchant marine

Rank	Country	Merchant marine	Rank	Country	Merchant marine
61	Saudi Arabia	72	107	Jordan	12
62	Egypt	67	108	Fiji	11
63	Monaco	64	109	Slovakia	11
64	Bangladesh	62	110	Pakistan	11
65	United Arab Emirates	61	111	Kazakhstan	11
66	Togo	61	112	Turkmenistan	11
67	Tuvalu	58	113	Latvia	11
68	Mongolia	57	114	Guyana	10
69	Venezuela	53	115	Brunei	9
70	Mexico	52	116	Tunisia	9
71	Luxembourg	49	117	Poland	9
72	Ecuador	44	118	Seychelles	9
73	Dominica	43	119	Bahrain	8
74	Chile	42	120	Israel	8
75	Australia	41	121	Ethiopia	8
76	Lithuania	38	122	Tonga	7
77	Algeria	38	123	Angola	7
78	Switzerland	38	124	Kenya	5
79	Faroe Islands	37	125	Oman	5
80	Argentina	36	126	Yemen	5
81	Cook Islands	35	127	Romania	5
82	Kuwait	34	128	Equatorial Guinea	5
83	Ireland	31	129	Mauritius	4
84	Papua New Guinea	31	130	Trinidad and Tobago	4
85	Lebanon	29	131	Ghana	4
86	Burma	29	132	Gambia, The	4
87	Qatar	28	133	Eritrea	4
88	Morocco	26	134	South Africa	3
89	Estonia	25	135	New Caledonia	3
90	Slovenia	24	136	Cuba	3
91	Libya	23	137	Austria	3
92	Peru	22	138	Micronesia, Federated States of	3
93	Bulgaria	22	139	Sao Tome and Principe	3
94	Sri Lanka	21	140	Sudan	2
95	Syria	19	141	Montenegro	2
96	Paraguay	19	142	Iraq	2
97	Maldives	18	143	Mozambique	2
98	Bolivia	18	144	Iceland	2
99	Albania	17	145	Gabon	2
100	Uruguay	16	146	Samoa	2
101	New Zealand	15	147	Czech Republic	1
102	Jamaica	14	148	Somalia	1
103	Jersey	14	149	Greenland	1
104	Cabo Verde	13	150	Senegal	1
105	French Polynesia	12	151	Congo, Democratic Republic of the	1
106	Colombia	12	152	Namibia	1

Table 5 (continued) Country Comparison: Merchant marine

Rank	Country	Merchant marine	Rank	Country	Merchant marine
153	Timor-Leste	1	155	Congo, Republic of the	1
154	Costa Rica	1	156	Madagascar	1

Freight Transportation: Global Highlights

2010



U.S. Department of Transportation
Research and Innovative Technology
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Introduction

To move large quantities of goods across the country and around the world, Americans depend on the Nation's freight transportation system—a vast network of roads, bridges, rail tracks, airports, seaports, navigable waterways, pipelines, and equipment. Today, U.S. households can buy fresh fruits and vegetables in mid-winter, expect fast and reliable next-day deliveries of Internet purchases, and use electronic appliances manufactured thousands of miles away, often in other countries. Because economic activities worldwide have become more integrated and globalized, more goods produced by U.S. factories and farms are bound for export, and imports originate from more than 200 countries. This pace of trade Americans have become accustomed to is made possible by the complex intermodal transportation network that blankets the country and links the United States with world markets.

The movement of international freight among nations relies on a complex array of long-distance transportation services. The process involves many participants, including shippers, commercial for-hire carriers, third-party logistics providers, and consignees. Moreover, global trade depends on seaport and airport services to move large volumes of merchandise over long distances via a variety of transportation modes. The interaction of these services and participants is vital to successful global trade.

In 2008, U.S. carriers received \$22 billion for commercial freight services provided to businesses in other countries. U.S. seaports and airports received \$36 billion for port services. U.S. firms paid \$45 billion to foreign carriers for freight services and \$27 billion to foreign ports for port services (USDOT BEA 2009).

ABOUT THIS REPORT

This report provides a snapshot of freight transportation activity from a global perspective, highlighting physical characteristics and industry output for the U.S. and other leading world economies. The report gives a broad overview of trends in the movement of international freight among the top 25 world economies, measured by 2008 gross domestic product (GDP). It presents recent statistics on freight activity by leading global ocean and air carriers, seaports, and airports engaged in international freight services.

The report also presents an overview of major trends in U.S. international goods trade, as well as trends in U.S. freight and port services. It further examines how U.S. international freight activities compare with those of the world's top economies. The report concludes with a brief discussion of the key factors that are driving change in U.S. and global merchandise trade and freight activities.

OVERVIEW

The United States has the largest freight transportation system in the world, an extensive physical network of infrastructure and entities that provide transportation services:

- 4 million miles of public roads,
- 140,000 miles of railroad tracks operated by freight carriers,
- 25,000 miles of navigable waterways,
- 9,800 coastal and inland waterway facilities, and
- 5,200 public-use airports (USDOT RITA BTS 2009a).

The U.S. transportation network serves more than 300 million people and 7.5 million business establishments across 3.8 million square miles of land. Moving raw materials and finished goods between production and consumption centers, this freight network is a vital component of commerce in the United States.

The United States is the world's largest economy and leading importing nation, accounting for 23 percent of world GDP and 13 percent of the value of world merchandise imports in 2008.¹ Before 2002, the United States was the world's largest merchandise exporter. Germany became the leading exporting nation that year, and China moved to the top position in 2008.²

Despite recent setbacks caused by the 2008 U.S. and global economic downturn, the movement of freight globally shows a long-term upward trend. From 1998 to 2008, world merchandise freight exports nearly tripled in value from \$5.4 trillion to \$16 trillion. During this period, U.S. freight exports doubled from \$682 billion to \$1.3 trillion (USDOC CB FTD 2009). The rising trend in world exports indicates the strong interconnectedness among countries and the increased globalization of economic activities that generate freight movements.

While virtually all countries export goods and the United States receives exports from more than 200 countries, the overwhelming majority of global exports are concentrated in only a few countries. In 2008, the concentration of world exports among the top trading nations was significant:

- more than half (51 percent) of the exports were from 10 countries,
- three-quarters (76 percent) were from 25 countries, and
- about 91 percent were from the top 50 countries.

¹ This report analyzes trends in U.S. and global international merchandise trade and freight in terms of value because aggregate data for both exports and imports by weight are not available for all modes of transportation.

² In this report, China refers to the People's Republic of China. Data for Hong Kong are reported separately.

OVERALL TRENDS

Freight is generated by economic activity and the freight industry tends to respond to fluctuations in this activity and the resultant level of trade among nations. The 2008 global economic downturn caused by the collapse of major financial markets resulted in declines in U.S. merchandise trade with partners around the world. From mid-2008 to early 2009, as the U.S. and global economies struggled, world trade sagged and the movement of international goods by service providers slowed. By the second quarter of 2009, demand for U.S. and global freight shipments had plummeted. Financial liquidity problems and fluctuations in energy prices affected all modes of freight transportation and all sectors of the freight industry.

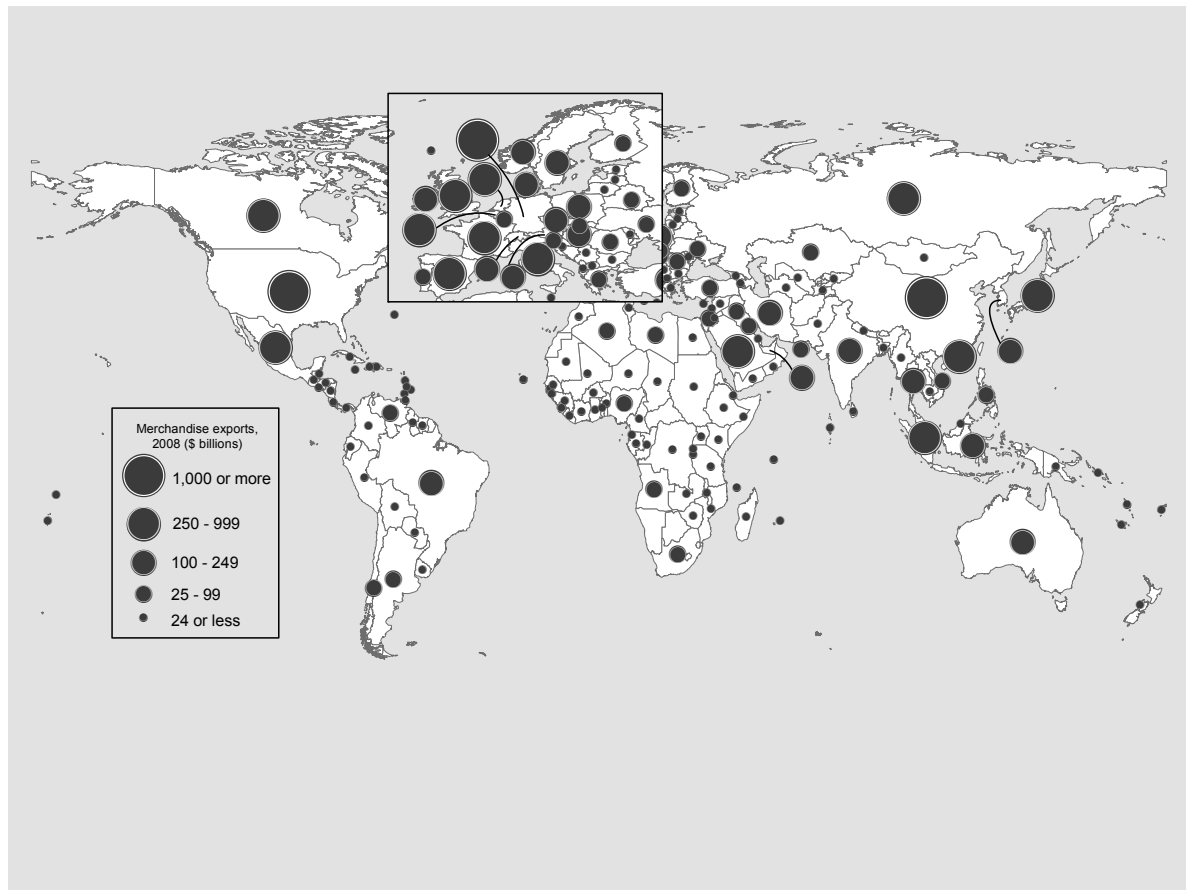
Before 2008, the global freight industry's primary challenge was growth in merchandise trade and the freight flows that strained system capacity. In 2009, declines in freight flows transformed the major challenge into the management of excess capacity. Shippers, carriers, and facility operators in the United States and around the world were forced to contract their freight operations in response to reduced trade volumes. By the end of September 2009, an estimated 548 container vessels with a carrying capacity of 1.3 million 20-foot equivalent units (TEUs) were idled at seaports worldwide as a result of the decline in global demand for containership services (AXS-Alphaliner 2009a).

The slowdown in economic activity in the United States and globally in 2008 and the subsequent reduction in U.S. consumer demand also affected international air cargo traffic and capacity. Global international air cargo, measured in freight ton-kilometers, fell 23 percent from 2007 (IATA 2009a).³ During the second half of 2008, air carriers around the world struggled with excess capacity and lower revenues. In particular, carriers were negatively affected by global reductions in oil prices. In principle, declining oil prices should have resulted in lower fuel costs for the airlines, but fuel-hedging contracts taken out at the start of the year when prices were much higher resulted in unexpected financial losses (IATA 2009a).⁴ By mid-2009, overall demand for air cargo and maritime freight had slowed because of weak economic activity and distressed financial markets.

³ This report uses metric ton-kilometers instead of ton-miles to describe trends in air cargo because it is the standard industry unit of measure when comparing air freight activity among countries. Most countries report their air cargo data in metric ton-kilometers.

⁴ Fuel hedging can negatively impact an airline if the price of jet fuel falls below the contracted price for future fuel deliveries, forcing the carrier to compete with those airlines purchasing fuel at the market rate. By mid-2008, crude oil sold for about \$140 a barrel. Prices declined to less than \$50 a barrel by end of the year as global economic activities slowed. Consequently, carriers who hedged in anticipation of higher prices recorded major losses in the fourth quarter of 2008.

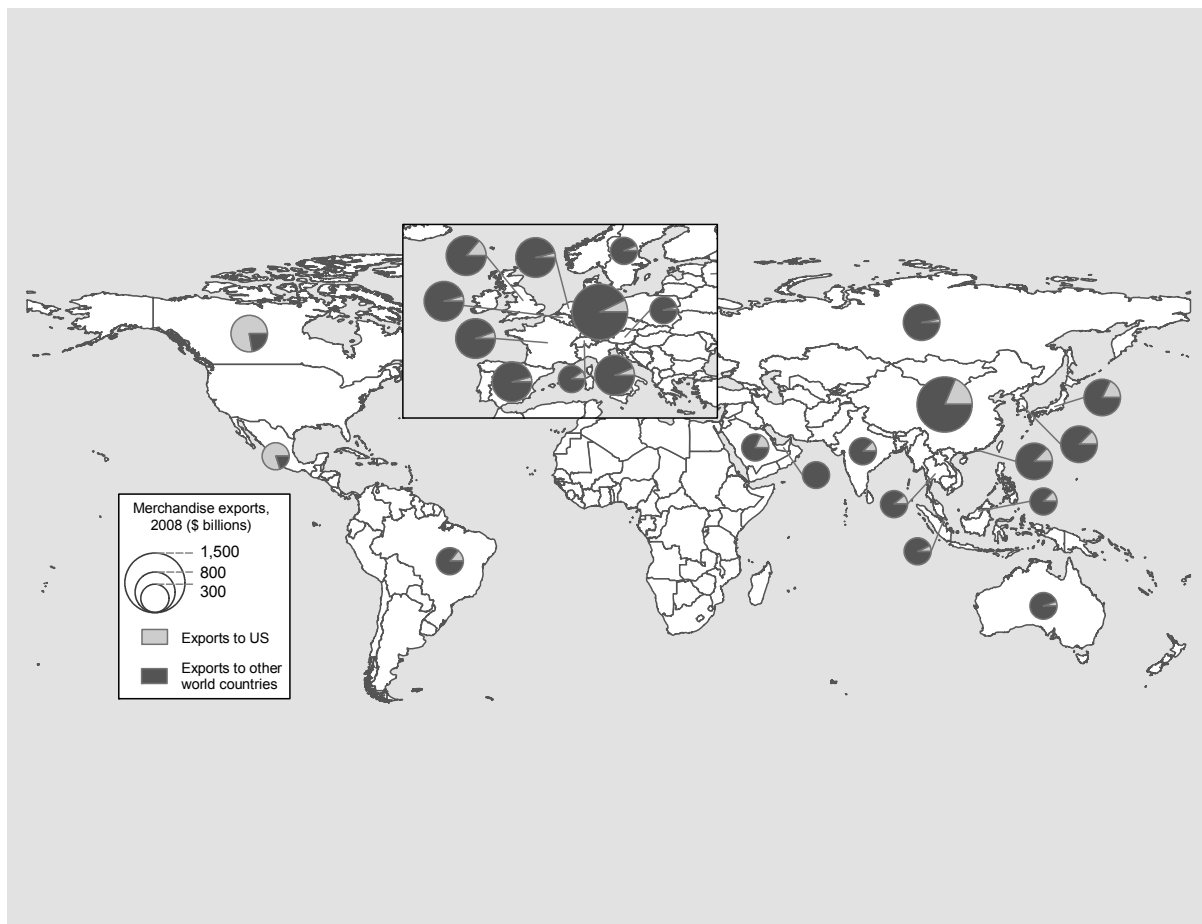
Figure 1. Value of World Goods Exports by Country: 2008



SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **United States**—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, available at www.census.gov/foreign-trade/www as of May 12, 2009. **World**—International Monetary Fund, Direction of Trade Statistics. Available at www.imfstatistics.org/dot/ as of Sept. 14, 2009.

- The global freight transportation infrastructure handles large volumes of cargo. In 2008, more than \$16 trillion of exported freight was transported worldwide. Maritime vessels, airplanes, trucks, and trains transported these goods from production centers to consumption markets.
- In 2008, the top three global merchandise exporters—China, Germany, and the United States—accounted for 26 percent of the value of total worldwide freight exports.

Figure 2. Goods Exports From Top Economies and Percent Share to the United States: 2008



SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **United States**—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, available at www.census.gov/foreign-trade/www as of May 12, 2009. **World**—International Monetary Fund, Direction of Trade Statistics. Available at www.imfstatistics.org/dot/ as of Sept. 14, 2009.

- In 2008, about 13 percent of world freight exports from more than 200 countries (\$2.1 trillion out of \$16 trillion) were bound for the United States. Of this amount, 55 percent was oceanborne cargo, 20 percent was air cargo, and about 25 percent was carried by land modes of transportation (USDOT CB FTD 2009).
- For the United States' top three trading partners, the proportion of their exports bound to the United States were:
 - Canada, 78 percent;
 - China, 19 percent; and
 - Mexico, 80 percent.

International Overview and Physical System



A significant proportion of global freight originates from the world's leading economies. In 2008, the world's top five economies by Gross Domestic Product GDP—the United States, Japan, China, Germany, and France—together accounted for:

- 35 percent of global goods exports (\$5.6 trillion out of \$16 trillion),
- 50 percent of global GDP (\$30.1 trillion out of \$60.9 trillion), and
- 28 percent of world population (1.9 billion out of 6.8 billion people).⁵

⁵ China accounted for more than 1.3 billion people.

OVERVIEW OF LEADING ECONOMIES

Table 1. World's Leading Economies by Gross Domestic Product: 1995, 2000, and 2008
(Ranked by 2008 GDP)

Rank in 1995	Rank in 2000	Rank in 2008	Country	Billions of current U.S. \$			Share of global GDP (percent)		
				1995	2000	2008	1995	2000	2008
			World	29,633	31,972	60,863	100.0	100.0	100.0
1	1	1	United States	7,398	9,817	14,265	25.0	30.7	23.4
2	2	2	Japan	5,278	4,669	4,924	17.8	14.6	8.1
8	6	3	China	728	1,198	4,402	2.5	3.7	7.2
3	3	4	Germany	2,525	1,906	3,668	8.5	6.0	6.0
4	5	5	France	1,572	1,333	2,866	5.3	4.2	4.7
5	4	6	United Kingdom	1,157	1,481	2,674	3.9	4.6	4.4
6	7	7	Italy	1,127	1,101	2,314	3.8	3.4	3.8
17	19	8	Russia	313	260	1,677	1.1	0.8	2.8
9	11	9	Spain	597	582	1,612	2.0	1.8	2.6
7	9	10	Brazil	770	644	1,573	2.6	2.0	2.6
10	8	11	Canada	591	725	1,511	2.0	2.3	2.5
14	13	12	India	354	462	1,210	1.2	1.4	2.0
16	10	13	Mexico	314	629	1,088	1.1	2.0	1.8
13	14	14	Australia	371	390	1,011	1.3	1.2	1.7
11	12	15	South Korea	539	534	947	1.8	1.7	1.6
12	15	16	The Netherlands	419	386	869	1.4	1.2	1.4
23	18	17	Turkey	228	266	729	0.8	0.8	1.2
31	25	18	Poland	139	171	526	0.5	0.5	0.9
24	28	19	Indonesia	223	166	512	0.8	0.5	0.8
18	22	20	Belgium	276	233	506	0.9	0.7	0.8
15	20	21	Switzerland	316	250	493	1.1	0.8	0.8
21	21	22	Sweden	254	246	485	0.9	0.8	0.8
30	24	23	Saudi Arabia	142	189	482	0.5	0.6	0.8
28	27	24	Norway	149	169	456	0.5	0.5	0.7
22	23	25	Austria	239	192	415	0.8	0.6	0.7

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from International Monetary Fund, World Economic Outlook Database, April 2009, available at www.imf.org as of Sept. 14, 2009.

- In 2008, the United States remained the world's leading economy, a position that directly reflects the level and composition of U.S. international freight transportation compared to that of the other large economies. China ranked third, a position that indicates its trade activity with the United States and freight shipments between the two countries.

Table 2. Geographic Overview of World's Top Economies: 2008

Ranked by population	National population (millions, July 2009 est.)	Population density (number of people per square kilometer)	Urban population (% of total national population, 2008)	Land area (thousands of square kilometers)
China	1,339	140	43	9,570
India	1,166	392	29	2,973
United States	307	34	82	9,162
Indonesia	240	133	52	1,812
Brazil	199	23	86	8,459
Russia	140	9	73	16,378
Japan	127	349	66	364
Mexico	111	57	77	1,944
Germany	82	236	74	349
Turkey	77	100	69	770
France	64	116	77	550
United Kingdom	61	253	90	242
Italy	58	198	68	294
South Korea	49	501	81	97
Spain	41	81	77	499
Poland	38	126	61	304
Canada	33	4	80	9,094
Saudi Arabia	29	13	82	2,150
Netherlands	17	493	82	34
Belgium	10	344	97	30
Sweden	9	22	85	410
Austria	8	100	67	82
Australia	8	0	89	7,682
Switzerland	8	190	73	40
Norway	5	15	77	304

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from Central Intelligence Agency, *Fact Book 2009*, available at www.cia.gov as of Sept. 20, 2009.

- The relatively larger area, lower population density, and higher urban population of the United States, in comparison to other countries, leads to relatively more freight activity. Freight must be transported greater distances as goods are shipped from production centers to consumers.

Table 3. Extent of Physical Transportation Systems in World's Top Economies: 2008

Ranked by total roadways	Roadways		Railways (km)	Waterways (km)	Pipelines (km)	Airports (number)
	Total (km)	Paved roads (km)				
United States	6,465,799	4,209,835	226,427	41,009	793,285	5,146
India	3,316,452	1,517,077	63,327	14,500	22,773	251
China	1,930,544	1,575,571	77,834	110,000	58,082	413
Brazil	1,751,868	96,353	28,857	50,000	19,289	734
Japan	1,196,999	949,101	23,506	1,770	4,082	144
Canada	1,042,300	415,600	46,688	636	98,544	514
France	951,500	951,500	29,213	8,501	22,804	295
Russia	933,000	754,984	87,157	102,000	246,855	596
Australia	812,972	341,448	37,855	2,000	30,604	462
Spain	681,224	681,224	15,288	1,000	11,743	154
Germany	644,480	644,480	41,896	7,467	31,586	331
Italy	487,700	487,700	19,729	2,400	18,785	101
Turkey	426,951	177,500	8,697	1,200	11,191	103
Sweden	425,300	139,300	11,633	2,052	786	249
Poland	423,997	295,356	22,314	3,997	15,792	126
United Kingdom	398,366	398,366	16,454	3,200	12,759	312
Indonesia	391,009	216,714	8,529	21,579	13,752	669
Mexico	356,945	178,473	17,516	2,900	40,016	243
Saudi Arabia	221,372	47,529	1,392	U	8,662	215
Belgium	152,256	119,079	3,233	2,043	2,023	42
Netherlands	135,470	113,018	2,811	6,215	4,897	27
Austria	107,262	107,262	6,399	358	3,541	55
South Korea	103,029	80,642	3,381	1,608	2,250	113
Norway	92,946	72,033	4,114	1,577	95	98
Switzerland	71,298	71,298	4,888	65	1,763	66

KEY: U = Data are unavailable.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from Central Intelligence Agency, *Fact Book 2009*, available www.cia.gov as of Sept. 20, 2009.

- The United States has the world's most extensive freight transportation network when measured in kilometers of public-use paved roads, railways, waterways, and pipelines, and number of airports.

Table 4. Intensity of Physical Transportation Systems of World's Top Economies: 2008

Ranked by total road miles per capita	Population density (number of people per square kilometer)	Total roadways		Paved roadways	
		Kilometers per capita (1,000 persons)	Roadway kilometers per square kilometer land area	Kilometers per capita (1,000 persons)	Roadway kilometers miles per square kilometer land area
Australia	0.4	105.8	0.04	44.4	0.02
Sweden	22	46.9	1.04	15.4	0.34
Canada	4	31.1	0.11	12.4	0.05
United States	34	21.0	0.71	13.7	0.46
Norway	15	19.9	0.31	15.5	0.24
Spain	81	16.8	1.37	16.8	1.37
France	116	14.9	1.73	14.9	1.73
Belgium	344	14.6	5.03	11.4	3.93
Austria	100	13.1	1.30	13.1	1.30
Poland	126	11.0	1.39	7.7	0.97
Japan	349	9.4	3.28	7.5	2.60
Switzerland	190	9.4	1.78	9.4	1.78
Brazil	23	8.8	0.21	0.5	0.01
Italy	198	8.4	1.66	8.4	1.66
Netherlands	493	8.1	4.00	6.8	3.33
Germany	236	7.8	1.85	7.8	1.85
Saudi Arabia	13	7.7	0.10	1.7	0.02
Russia	9	6.7	0.06	5.4	0.05
United Kingdom	253	6.5	1.65	6.5	1.65
Turkey	100	5.6	0.55	2.3	0.23
Mexico	57	3.2	0.18	1.6	0.09
India	392	2.8	1.12	1.3	0.51
Korea	501	2.1	1.06	1.7	0.83
Indonesia	133	1.6	0.22	0.9	0.12
China	140	1.4	0.20	1.2	0.16

NOTE: In this report, intensity is defined as a ratio of the extent of the physical transportation system to the geographical area it covers and to population size. It indicates the relative concentration of the infrastructure and the size that is available for use by the population.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from Central Intelligence Agency, *Fact Book 2009*, available at www.cia.gov as of Sept. 20, 2009.

- When road networks are viewed in relation to total land area, countries such as Japan, the United Kingdom, and France have at least twice as many kilometers of roadways per square kilometer of land area as the United States. However, if road networks are viewed in relation to population, those three countries have fewer roadway kilometers per person than the United States—the result of the lower population density and vast geographic expanse of the United States.

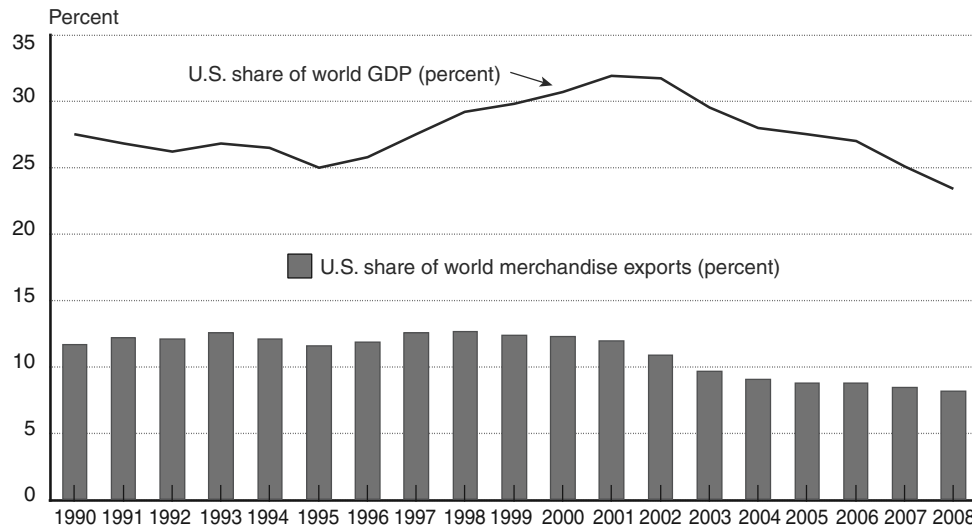
**Table 5. U.S. Share of World Gross Domestic Product:
1990–2008**
(Billions of current U.S. \$)

Year	World GDP	United States GDP	U.S. share of world GDP (percent)
1990	21,137	5,803	27.5
1991	22,386	5,996	26.8
1992	24,235	6,338	26.2
1993	24,860	6,657	26.8
1994	26,695	7,072	26.5
1995	29,633	7,398	25.0
1996	30,353	7,817	25.8
1997	30,240	8,304	27.5
1998	29,970	8,747	29.2
1999	31,103	9,268	29.8
2000	31,972	9,817	30.7
2001	31,744	10,128	31.9
2002	33,052	10,470	31.7
2003	37,140	10,961	29.5
2004	41,809	11,686	28.0
2005	45,183	12,422	27.5
2006	48,882	13,178	27.0
2007	54,999	13,808	25.1
2008	60,863	14,265	23.4

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from International Monetary Fund, World Economic Outlook Database, April 2009, available at www.imf.org, as of Sept. 14, 2009.

- Trends in global economic activities directly affect the volume of merchandise trade and worldwide movement of freight. The growing reliance on global supply chains means the effect of an economic downturn is not limited to exporting and importing nations. Other nations that provide freight and port services to transport traded goods are also affected.
- Between 2001 and 2008, the U.S. share of world GDP declined as the share of emerging and developing economies grew. Many other factors contributed to this trend, including foreign currency exchange rates, business cycles, balance of payments, and central banks policies—all of which affect the value of internationally traded goods.

Figure 3. U.S. Share of World Gross Domestic Product and Merchandise Exports: 1990–2008



SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources: **GDP**—International Monetary Fund, World Economic Outlook Database, April 2009. Available at www.imf.org/external/data.htm as of Sept. 14, 2009. **Trade**—International Monetary Fund, Direction of Trade Statistics. Available at www.imfststatistics.org/dot/ as of Sept. 14, 2009.

- The U.S. share of world GDP and merchandise exports increased from 1995 to 2001 during the “dot-com boom” period of U.S. economic expansion. Since 2001, the expansion of developing economies in Asia—notably China’s economy—contributed to the decline of the U.S. share of world GDP and merchandise exports.
- Top goods exports from the United States include civilian aircraft and parts, motor vehicles and parts, electrical equipment, electronics, and medical equipment (USDOT CB FTD 2009).

WORLD AND U.S. INTERNATIONAL FREIGHT

Table 6. World's Top Merchandise Exporting Countries and Their Exports to the United States: 2008
(Millions of current U.S. \$)

Rank in 2008	Country	Total exports	Share of world total exports (percent)	Exports to United States	Exports to U.S. as share of country's total (percent)
NA	World	16,044,000	100.0	2,063,720	12.9
1	China	1,469,280	9.2	273,129	18.6
2	Germany	1,465,200	9.1	104,728	7.1
3	United States	1,300,190	8.1	NA	NA
4	Japan	783,149	4.9	139,022	17.8
5	Netherlands	633,842	4.0	24,837	3.9
6	France	606,623	3.8	35,013	5.8
7	Italy	539,933	3.4	33,905	6.3
8	Belgium	477,159	3.0	23,095	4.8
9	United Kingdom	460,693	2.9	63,765	13.8
10	Canada	456,485	2.8	354,687	77.7
11	Russia	456,075	2.8	15,285	3.4
12	Korea	426,763	2.7	46,501	10.9
13	Hong Kong	362,985	2.3	46,290	12.8
14	Singapore	339,414	2.1	24,196	7.1
15	Mexico	291,343	1.8	233,523	80.2
16	Saudi Arabia	285,928	1.8	51,823	18.1
17	Spain	267,581	1.7	11,229	4.2
18	Malaysia	224,490	1.4	28,321	12.6
19	Switzerland	200,065	1.2	19,221	9.6
20	Brazil	197,067	1.2	28,558	14.5
21	India	191,926	1.2	24,483	12.8
22	Australia	185,693	1.2	10,290	5.5
23	Sweden	184,000	1.1	12,091	6.6
24	Austria	181,737	1.1	7,802	4.3
25	Thailand	173,235	1.1	19,754	11.4
	Rest of the world	3,883,144	24.2	432,171	11.1

KEY: NA= Not applicable.

NOTE: Hong Kong is a special administrative region of China, but is separate from China in U.S. Foreign Trade Statistics.

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **United States**—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, available at www.census.gov as of May 12, 2009. **World**—International Monetary Fund, Direction of Trade Statistics. Available at www.imfstatistics.org as of Sept. 14, 2009.

- In 2008, the United States was the world's third-ranked exporting nation, behind China and Germany. U.S. goods exports accounted for 8 percent of the value of worldwide exports.
- Among the world's top exporting nations, Canada and Mexico ranked 10th and 15th, respectively.
- The majority of exports from Canada and Mexico continue to be bound for the United States. Most enter by surface modes of transportation.
- The United States received nearly one-fifth (19 percent) of the exports from China. The top exports from China to the United States include finished goods such as computer equipment, electronics, toys, apparel, furniture, and other household goods.

Table 7. World's Top Merchandise Importing Countries and Their Imports From the United States: 2008
(Millions of current U.S. \$)

Rank in 2008	Country	Total imports	Share of world total imports (percent)	Imports from United States	Imports from U.S. as share of country's total (percent)
NA	World	16,708,900	100.0	1,340,520	8.0
1	United States	2,166,020	13.0	NA	NA
2	Germany	1,204,750	7.2	50,399	4.2
3	China	1,196,750	7.2	80,723	6.7
4	Japan	761,803	4.6	78,974	10.4
5	France	706,670	4.2	30,274	4.3
6	United Kingdom	634,542	3.8	55,192	8.7
7	Netherlands	573,758	3.4	43,368	7.6
8	Italy	556,328	3.3	17,355	3.1
9	Belgium	470,194	2.8	26,112	5.6
10	Canada	449,077	2.7	235,479	52.4
11	South Korea	435,275	2.6	38,556	8.9
12	Spain	403,045	2.4	13,893	3.4
13	Hong Kong	388,947	2.3	19,541	5.0
14	Mexico	339,464	2.0	166,468	49.0
15	Singapore	319,779	1.9	37,853	11.8
16	India	304,166	1.8	20,533	6.8
17	Russia	274,284	1.6	12,204	4.4
18	Brazil	229,877	1.4	34,233	14.9
19	Australia	211,111	1.3	25,346	12.0
20	Poland	205,148	1.2	2,973	1.4
21	Turkey	201,964	1.2	11,977	5.9
22	United Arab Emirates	190,203	1.1	17,324	9.1
23	Austria	184,501	1.1	3,306	1.8
24	Switzerland	183,002	1.1	10,612	5.8
25	Malaysia	181,851	1.1	14,543	8.0
	Rest of the world	3,936,391	23.6	293,284	7.5

KEY: NA= Not applicable.

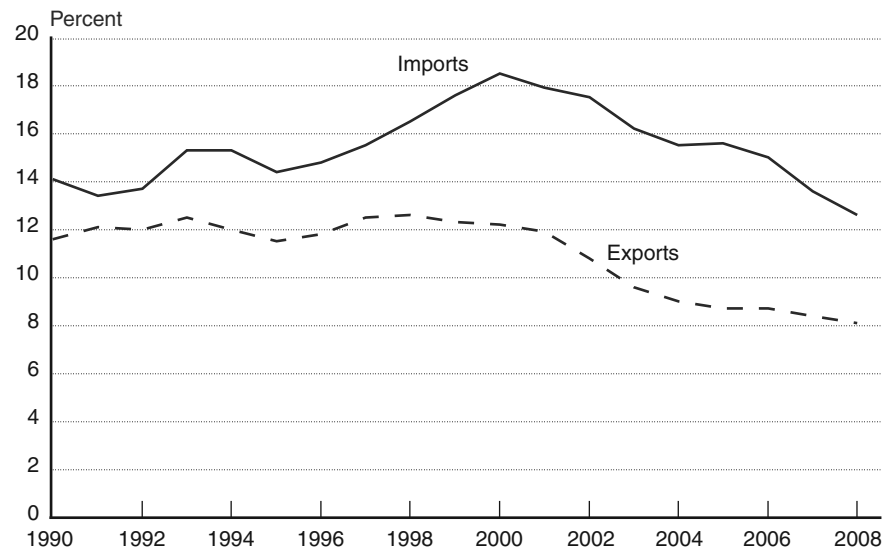
NOTE: Hong Kong is a special administrative region of China, but is separate from China in U.S. Foreign Trade Statistics.

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **United States**—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, available at www.census.gov as of May 12, 2009. **World**—International Monetary Fund, Direction of Trade Statistics, available at www.imfstatistics.org as of Sept. 14, 2009.

- The United States is the world's largest importer of goods. Crude oil, petroleum products, passenger motor vehicles, electrical machinery, and electronics are among the top imports by value (USDOT CB FTD 2009).
- Canada, Mexico, and Brazil's imports from the United States account for a large proportion of their overall imports.
- Over half of Canada's imports are from the United States. Canada's top imports from the United States include passenger cars, trucks, buses, vehicle parts, and civilian aircraft.
- Nearly half of Mexico's imports are from the United States. The top imports from the United States are motor vehicles and parts, electronic equipment and parts, electrical apparatus, and petroleum products.

- The United States accounted for about 15 percent of imports into Brazil, an important emerging economy. Top imports into Brazil from the United States include civilian aircraft and parts, computer equipment, and telecommunications equipment.
- In 2008, China imported less from the United States (\$81 billion) than it exported to the United States (\$273 billion). Its imports from the United States accounted for 7 percent of the country's total imports, and its exports to the United States accounted for 19 percent of its total exports.

Figure 4. U.S. Share of World Merchandise Trade: 1990–2008



SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **United States**—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, available at www.census.gov/foreign-trade/index.html as of May 12, 2009. **World**—International Monetary Fund, Direction of Trade Statistics. Available at www.imfstatistics.org/dot/ as of Sept. 14, 2009.

- From 1990 to 2008, the U.S. share of the world's total imports was larger than its share of exports. During this period, the U.S. share of total exports fell faster than its share of the world's total imports (IMF 2009).

Worldwide Oceanborne and Air Freight



Stock photo

Businesses rely on all freight modes to transport international merchandise trade. Often, goods are moved by a multimodal combination of airplanes, maritime vessels, trains, and trucks.

Figure 5. Worldwide Oceanborne Cargo

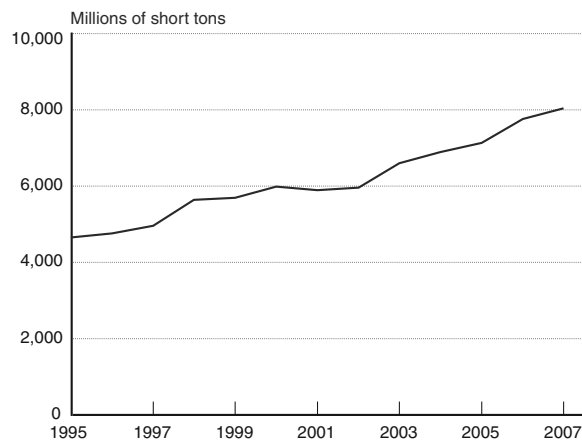
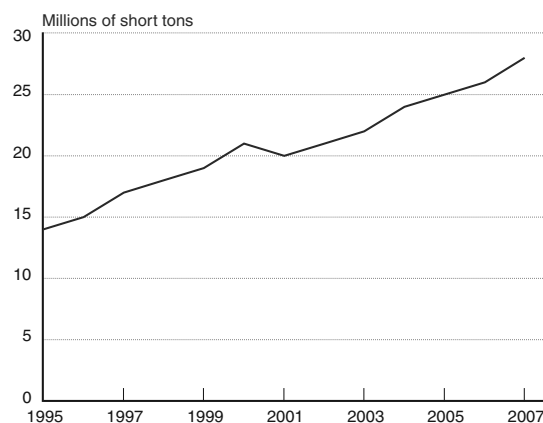


Figure 6. Worldwide Air Cargo

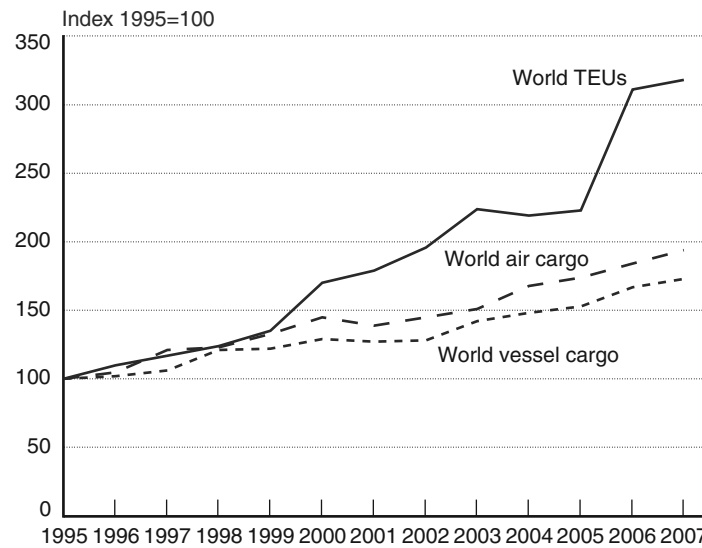


NOTE: Although figures 5 and 6 are not to the same scale, they both show nearly a doubling of cargo, by weight, over identical time spans.

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **Oceanborne cargo**—United Nations Conference on Trade and Development, Review of Maritime Transport, various issues, available at www.unctad.org/rmt as of Oct. 3, 2009. **Air cargo**—International Civil Aviation Organization (ICAO), special tabulations, Sept. 28, 2009.

- In 2007, the most recent year for which data are available, the volume of worldwide international oceanborne cargo reached more than 8 billion tons. During the past decade, the annual average growth rate was about 3 percent.
- Worldwide international air cargo reached 28 million tons in 2007, growing at an annual average rate of 5 percent over the past decade. This growth trend reflects continuing globalization of economic activities and increasing adoption of inventory management strategies.
- By weight, the overwhelming majority of global overseas merchandise trade is carried by ocean vessel rather than airplane (excluding land modes of transportation). While generally ocean vessels transport low value-per-ton commodities (e.g., crude oil, grains, and coal), container vessels transport high value-per-ton manufactured goods of all kinds, such as automobiles, appliances, computer equipment, and apparel.

Figure 7. Worldwide Overseas Oceanborne and Air Cargo by Weight: 1995–2007



SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **Oceanborne cargo**—United Nations Conference on Trade and Development, Review of Maritime Transport, various issues, available at www.unctad.org/rmt as of Oct. 3, 2009. **Air cargo**—International Civil Aviation Organization (ICAO), special tabulations, Sept. 28, 2009.

- By weight, air carriers carry less global merchandise trade than ocean vessels. Air carriers transport high value-per-ton commodities. During the past decade, however, the tonnage of air cargo transported globally grew at a faster rate than total oceanborne cargo.
- Air cargo tonnage grew as demand for international express traffic increased and shippers sought more time-definite deliveries. While ocean carriers provide lower transportation costs, air carriers provide faster delivery times.
- Containerized cargo, a segment of the maritime industry that, like air cargo, includes high value-per-ton goods, grew faster than air cargo and total oceanborne cargo during this period.

Table 8. Value and Weight of Worldwide and U.S. Oceanborne Export Freight: 1995–2007

Year	World exports		U.S. exports	
	Value (billions U.S. \$)	Weight (millions of short tons)	Value (billions U.S. \$)	Weight (millions of short tons)
1995	2,252	4,651	228	475
1996	2,354	4,758	238	451
1997	2,422	4,953	225	432
1998	2,243	5,631	192	405
1999	2,354	5,683	182	400
2000	3,027	5,984	199	415
2001	2,901	5,891	199	399
2002	2,979	5,948	191	384
2003	3,646	6,598	206	373
2004	4,551	6,893	234	416
2005	5,290	7,122	263	402
2006	6,301	7,761	308	434
2007	7,723	8,032	375	467

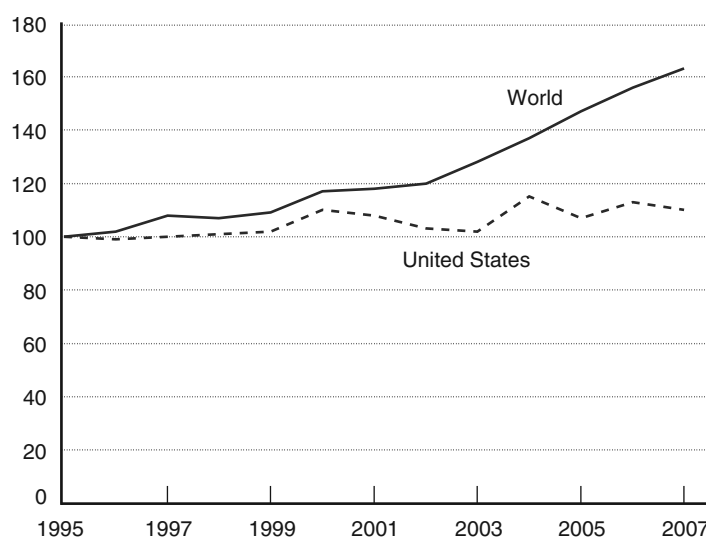
SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources.

World: Value—IHS Global Insight World Trade Service, special tabulations from June 2009 Forecast Series, as of Sept. 29, 2009. **Weight**—United Nations Conference on Trade and Development, Review of Maritime Transport, various issues, available at www.unctad.org as of Oct. 3, 2009.

United States: Value—U.S. Department of Transportation, Maritime Administration, available at www.marad.gov as of Oct. 2, 2009. **Weight**—U.S. Army Corps of Engineers, Waterborne Commerce of the United States 2007, Table 1-6, available at www.iwr.usace.army.mil as of Oct. 2, 2009.

- Between 1995 and 2007, world oceanborne export freight, as measured by weight, nearly doubled to 8 billion short tons. By comparison, the total weight of U.S. oceanborne exports remained steady.
- The weight, value, and physical characteristics of oceanborne cargo determine the type of vessels used for particular shipments (tanker, container, or bulk) and the seaports where they call. In 2008, Houston was the leading U.S. port by weight and Los Angeles was the top container port (USDOT RITA BTS 2009b).

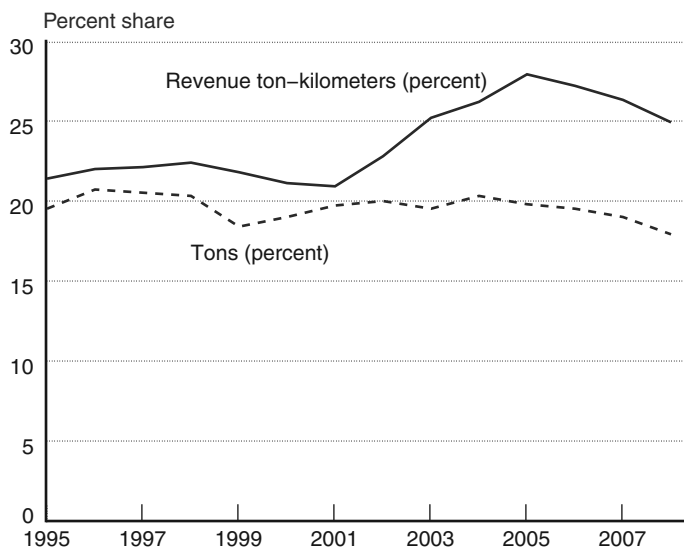
Figure 8. Worldwide and U.S. Maritime Industry Ton-Miles: 1995–2007



SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **World**—United Nations Conference on Trade and Development, Review of Maritime Transport, various issues, available at www.unctad.org/rmt as of Oct. 3, 2009. **United States**—U.S. Army Corps of Engineers, Waterborne Commerce of the United States 2007, Table 1-6, available at www.iwr.usace.army.mil/ndc/wcsc/wcsc.htm as of Oct. 2, 2009.

- During the past decade, the demand for maritime freight services, as measured by ton-miles, grew faster globally than for U.S. international freight. From 1995 to 2007, global maritime ton-miles grew at an average annual rate of 4 percent. Ton-miles grew less than 1 percent for the United States over the same period.
- Global ton-miles grew faster as China and other countries increased oil imports from places other than the Middle East (e.g., Angola) and increased purchases of dry bulk cargo (e.g., iron ore) from South America (UNCTAD 2008).

Figure 9. U.S. Air Carriers' Share of Worldwide International Tons and Revenue Ton-Kilometers: 1995-2008



NOTE: The U.S. data were converted from short ton-miles to ton-kilometers. To convert short ton-miles to metric ton-kilometers, first multiply by 1.61 (for kilometers) and then divide by 1.1 (for metric tons).

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **World**—International Civil Aviation Organization (ICAO), special tabulations, Sept. 28, 2009. **United States**—USDOT, RITA, BTS, Office of Airline Information, TranStats—tonnage: T100-Segment data (U.S. carriers only); ton-kilometers: T2-U.S. Air Carrier Traffic and Capacity Statistics, available at www.bts.gov as of Sept. 29, 2009.

- In 2008, U.S. air carriers carried about 4.4 million tons of international air cargo, accounting for 18 percent of the 25 million tons transported globally in international service. U.S. air carriers' international cargo traffic generated 33 billion revenue ton-kilometers, accounting for 25 percent of about 131 billion revenue ton-kilometers of global international air cargo traffic.
- Since 2005, the U.S. share of world air cargo tonnage and ton-kilometers has declined as the annual growth rates of Asia's air cargo markets increased.

Worldwide Ports



E-Ternational

Seaports and airports are vital components of the freight system. They enable global trade and facilitate international economic activities.

In 2007, ports worldwide handled more than 8 billion tons of oceanborne exports and more than 25 million tons of international air cargo. This freight included raw materials, manufactured products, and everyday items found at businesses and homes, such as laptop computers, precision medical instruments, flat-panel televisions, bicycles, and furniture.

Table 9. Leading World Maritime Ports by Cargo Weight: 2007
(Thousands of metric tons)

Rank	Port name	Country	Tons
1	Shanghai	China	561,446
2	Singapore	Singapore	483,616
3	Ningbo-Zhoushan	China	471,630
4	Rotterdam	Netherlands	401,181
5	Guangzhou	China	341,363
6	Tianjin	China	309,465
7	Qingdao	China	265,020
8	Qinhuangdao	China	245,964
9	Hong Kong	China	245,433
10	Busan	South Korea	243,564
11	Dalian	China	222,859
12	Nagoya	Japan	215,602
13	South Louisiana	United States	207,785
14	Shenzhen	China	199,190
15	Kwangyang	South Korea	198,190
16	Houston	United States	196,014
17	Antwerp	Belgium	182,897
18	Chiba	Japan	169,202
19	Ulsan	South Korea	168,652
20	Kaohsiung	Taiwan	149,225
21	New York/New Jersey	United States	142,614
22	Yokohama	Japan	141,758
23	Hamburg	Germany	140,923
24	Incheon	South Korea	138,139
25	Port Kelang	Malaysia	135,514

NOTE: The original source of the data in this table, the American Association of Port Authorities, notes that the metric tons used for the rankings are estimates from various sources, including the individual seaports, and are based on cargo weights, volumes, and units. As such, the figures cannot be converted into a single standardized measure such as TEUs. Because of this, the estimates are also not directly comparable across all seaports.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from American Association of Port Authorities. Port Industry Statistics. World Port Rankings: 2007, available at www.aapa-ports.org as of Sept. 30, 2009.

- By weight, 7 of the world's top 10 seaports in 2007 were in China. Three U.S. ports—South Louisiana, Houston, and New York/New Jersey—ranked among the top 25.

Table 10. Top 20 World Container Ports by TEUs Handled: 2007 and 2008
(Thousands of loaded and unloaded TEUs)

Rank in 2008	Port name	Country	2007	2008	Percent change, 2007–2008
1	Singapore	Singapore	27,932	29,918	7.1
2	Shanghai	China	26,150	27,980	7.0
3	Hong Kong	China	23,881	24,248	1.5
4	Shenzhen	China	21,099	21,414	1.5
5	Busan	South Korea	13,270	13,425	1.2
6	Dubai	United Arab Emirates	10,653	11,828	11.0
7	Ningbo	China	9,360	11,226	19.9
8	Guangzhou	China	9,200	11,001	19.6
9	Rotterdam	Netherlands	10,791	10,800	0.1
10	Qingdao	China	9,462	10,320	9.1
11	Hamburg	Germany	9,900	9,700	-2.0
12	Kaohsiung	Taiwan	10,257	9,677	-5.7
13	Antwerp	Belgium	8,177	8,664	6.0
14	Tianjin	China	7,103	8,500	19.7
15	Port Klang	Malaysia	7,120	7,970	11.9
16	Los Angeles	United States	8,355	7,850	-6.0
17	Long Beach	United States	7,312	6,488	-11.3
18	Tanjung Pelepas	Malaysia	5,500	5,600	1.8
19	Bremen/Bremerhaven	Germany	4,892	5,501	12.4
20	New York/New Jersey	United States	5,400	5,265	-2.5

KEY: TEUs = twenty-foot equivalent units. One 20-foot container equals one TEU, and one 40-foot container equals two TEUs.

SOURCES: 2000 and 2007—U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on Maritime Administration, 2008—Containerisation International Online, www.ci-online.co.uk as of Mar. 17, 2009.

- In 2008, three U.S. ports—Los Angeles, Long Beach, and New York/New Jersey—ranked among the top 20 world container ports. Six of the top 10 were in China.

**Table 11. Top World Airports for International Air Freight by Tons Handled:
January to June 2009
(Thousands of metric tons)**

Rank	Airport	City and country	January–June 2009
1	Hong Kong	Hong Kong, China	1,462
2	Incheon	Incheon, South Korea	1,031
3	Dubai	Dubai, United Arab Emirates	835
4	Narita	Tokyo, Japan	784
5	Frankfurt	Frankfurt, Germany	782
6	Changi	Singapore, Singapore	754
7	Pu Dong	Shanghai, China	723
8	Miami	Miami, United States	629
9	Schiphol	Amsterdam, The Netherlands	587
10	Heathrow	London, United Kingdom	583
11	Taiwan Taoyuan	Taipei, Taiwan	551
12	Ted Stevens Anchorage	Anchorage, United States	518
13	Bangkok	Bangkok, Thailand	444
14	John F. Kennedy	New York, United States	372
15	Los Angeles	Los Angeles, United States	360
16	O'Hare	Chicago, United States	313
17	Luxembourg-Findel	Luxembourg, Luxembourg	300
18	Beijing	Beijing, China	288
19	Koln Bonn	Cologne, Germany	254
20	Kuala Lumpur	Kuala Lumpur, Malaysia	238
21	Kansai	Osaka, Japan	235
22	Liege-Bierset	Liege, Belgium	213
23	Leipzig-Halle	Leipzig, Germany	204
24	Brussels	Brussels, Belgium	190
25	Sharjah	Sharjah, United Arab Emirates	185

NOTE: Total tons handled—loaded and unloaded freight and mail in metric tons.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from Airports Council International, available at www.aci.aero as of Sept. 29, 2009.

- By June 2009, five U.S. airports—Miami, Ted Stevens Anchorage, John F. Kennedy, Los Angeles, and O'Hare—ranked among the world's leading airports for international air cargo traffic as measured by tons handled.

Table 12. Top World Airports for International Air Freight by Tons Handled: 2007–2008
(Thousands of metric tons)

Rank in 2008	Airport	City and country	2007	2008	Percent change, 2007–2008
1	Hong Kong	Hong Kong, Hong Kong	3,742	3,627	-3.1
2	Incheon	Incheon, South Korea	2,524	2,386	-5.4
3	Narita	Tokyo, Japan	2,212	2,059	-6.9
4	Charles de Gaulle	Paris, France	1,994	2,010	0.8
5	Frankfurt Main	Frankfurt, Germany	2,030	1,963	-3.3
6	Pudong	Shanghai, China	1,826	1,916	4.9
7	Changi	Singapore, Singapore	1,895	1,857	-2.0
8	Dubai	Dubai, United Arab Emirates	1,591	1,741	9.4
9	Schiphol	Amsterdam, The Netherlands	1,610	1,568	-2.6
10	Miami	Miami, United States	1,611	1,544	-4.2
11	Taiwan Taoyuan	Taipei, Taiwan	1,593	1,480	-7.1
12	Ted Stevens Anchorage	Anchorage, United States	1,663	1,404	-15.5
13	Heathrow	London, United Kingdom	1,313	1,400	6.6
14	Bangkok	Bangkok, Thailand	1,178	1,140	-3.2
15	John F. Kennedy	New York, United States	1,179	1,054	-10.6
16	O'Hare	Chicago, United States	1,022	887	-13.2
17	Los Angeles	Los Angeles, United States	1,005	880	-12.4
18	Luxembourg-Findel	Luxembourg, Luxembourg	856	788	-8.0
19	Kansai	Osaka, Japan	764	753	-1.4
20	Beijing	Beijing, China	549	639	16.3
21	Brussels	Brussels, Belgium	738	604	-18.1
22	Kuala Lumpur	Kuala Lumpur, Malaysia	585	592	1.2
23	Koln Bonn	Cologne, Germany	672	557	-17.1
24	Liege-Bierset	Liege, Belgium	490	518	5.7
25	El Nuevo Dorado	Bogota, Columbia	433	429	-0.9

NOTE: Total tons handled—loaded and unloaded freight and mail in metric tons.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from Airports Council International, available at www.aci.aero as of Sept. 29, 2009.

- In 2008, most of the world's leading airports for handling international cargo experienced declines in freight traffic compared to the previous year.
- All 5 U.S. airports ranked among the world's top 25 air freight airports —Miami, Ted Stevens Anchorage, John F. Kennedy, O'Hare, and Los Angeles—shipped less freight in 2008 than in 2007.

Worldwide Freight Carriers



Nina Chantasm

Shipping lines, airlines, all-cargo air couriers, trucking firms, and railroads provide services that link shippers, ports, and consignees. Managing product supply chains and transporting goods globally involves considerable interaction across the carrier industry. During the past decade, businesses expanded sourcing of raw materials and finished goods from multiple locations around the world, and the air and ocean freight carrier industries that provide overseas services adapted their freight operations in response.

Globally, the leading all-cargo air carriers include FedEx, UPS, DHL, and TNT. Leading airlines that provide cargo services include Lufthansa, Korean Air Lines, Singapore Airlines, British Airways, and Air France (IATA 2009b). The air-freight carrier industry continued its heavy reliance on hub-and-spoke operations⁶ that allow carriers to connect several origins with multiple destinations without having all the points connected directly.

⁶ Hub-and-spoke operations describe a route structure in which airlines arrange flights like a wheel with all traffic moving along spokes to and from a central location—the hub. In the 1980s, most airlines changed their operations from a linear point-to-point network to a hub-and-spoke network (USDOT RITA BTS 1996).

Expanded use of hub networks allowed the airlines to control fleet size and capacity while serving many markets. It also allowed them to cut operating costs and offer improved integrated cargo delivery services. Airlines that carry commercial freight in aircraft cargo holds during passenger flights continued to expand their cargo services beyond their immediate networks by forming alliances. Examples of industry alliances among the leading airlines include United-Lufthansa, Northwest-KLM, Delta-China Airlines, and American Airlines-Mexicana Airlines.

Worldwide, the leading ocean container carriers include APM-Maersk Line, Mediterranean Shipping Company, CMA CGM, Evergreen Line, and American President Lines (APL) (AXS-Alphaliner 2009b). During the past decade, the ocean-shipping industry continued consolidations begun in the 1990s. Carriers engaged in vessel-sharing arrangements⁷ that allowed them to serve multiple ports by connecting to larger hub seaports. These hub ports provide feeder vessel services to smaller ports and often use intermodal rail and truck carriers for deliveries to final destinations. Some of the major inter-carrier alliances, mergers, and acquisitions include Maersk and Sea-Land, Neptune Orient Line and APL, and Maersk and P&O Nedlloyd.

In April 2008, the world's three largest container lines—Danish carrier Maersk Line, Swiss carrier Mediterranean Shipping Company, and French-based CMA–CGM—started a significant vessel-sharing agreement in the Asia-North America trade lane that enables them to replace their own individual services with joint services (Maersk Line 2008). In September 2009, Maersk Line and CMA CGM merged services between the east coast of South America, Central America, and the Caribbean (Maersk Line 2009).

**Table 13. Leading World Maritime Container Carriers by Fleet Size: September 2009
(Ranked by TEUs)**

Rank	Carrier	Company	Country of owner	Fleet size (TEUs in thousands)	Ships
1	APM-Maersk Line	A. P. Moller-Maersk Group	Denmark	2,035	539
2	Mediterranean Shipping Company	Mediterranean Shipping Company S.A.	Switzerland	1,509	406
3	CMA CGM	CMA CGM Group	France	1,021	359
4	Evergreen Line	Evergreen Marine	Taiwan	589	160
5	APL	American President Lines	Singapore	550	139
6	Hapag-Lloyd	Hapag-Lloyd	Germany	469	116
7	COSCO Container Line	China Ocean Shipping Company	China	466	144
8	CSCCL	China Shipping Container Lines	China	461	140
9	NYK	Nippon Yusen Kaisha	Japan	413	109
10	Hanjin Shipping	Hanjin Shipping	South Korea	409	92
11	MOL	Mitsui O.S.K. Lines	Japan	343	93
12	K Line	Kawasaki Kisen Kaisha	Japan	331	90
13	OOCL	Orient Overseas Container Line	Hong Kong	329	71
14	Hamburg Süd Group	Wallenius Wilhelmsen Logistics	Sweden	326	108
15	Yang Ming Line	Mediterranean Shipping Company S.A.	Switzerland	314	78
16	CSAV Group	Compañía Sud Americana de Vapores	Chile	294	89
17	Zim	Zim Integrated Shipping Services	Israel	271	88
18	Hyundai M.M.	Hyundai Merchant Marine	South Korea	266	52
19	PIL	Pacific International Lines	Singapore	191	107
20	UASC	United Arab Shipping Company	Kuwait	171	45
21	Wan Hai Lines	Wan Hai Lines	Taiwan	130	68
22	IRIS Lines	Islamic Republic of Iran Shipping Lines	Iran	108	65
23	Orient Overseas International Line	Orient Overseas International Limited	Hong Kong	100	33
24	Sea Consortium	Sea Consortium	Singapore	57	52
25	RCL	Regional Container Lines	Thailand	51	39

KEY: TEUs = twenty-foot equivalent units. One 20-foot container equals one TEU, and one 40-foot container equals two TEUs.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from AXS-Alphaliner, available at www.axs-alphaliner.com/top100/index.php as of Sept. 28, 2009.

Table 14. Leading World Air Carriers by Weight of International Cargo Handled: 2008

Rank	Airline	Thousands of tons
1	FedEx	1,891
2	UPS	1,603
3	Korean Air	1,438
4	Emirates	1,382
5	Cathay Pacific Airways	1,339
6	Singapore Airlines	1,274
7	United Airlines	1,257
8	Lufthansa	1,157
9	China Airlines	1,086
10	Cargolux	794
11	Air France	786
12	European Air Transport (EAT)	733
13	British Airways	708
14	EVA Air	681
15	Japan Airlines	679
16	Asiana Airlines	672
17	KLM–Royal Dutch Airlines	604
18	Thai Airways	536
19	LAN	503
20	Malaysia Airlines	468
21	Air China	429
22	China Eastern Airlines	421
23	Qatar Airways	402
24	Northwest Airlines	345
25	American Airlines	336

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from International Air Transport Association, *World Air Transport Statistics, 53rd Edition*, www.iata.org as of Oct. 16, 2009.

- The top world air carriers, FedEx and UPS, also own and operate a fleet of trucks and use rail service to provide multimodal shipping services to shippers.
- United, Northwest, and American, ranked here among the top 25 global carriers for international cargo, are best known for passenger service.

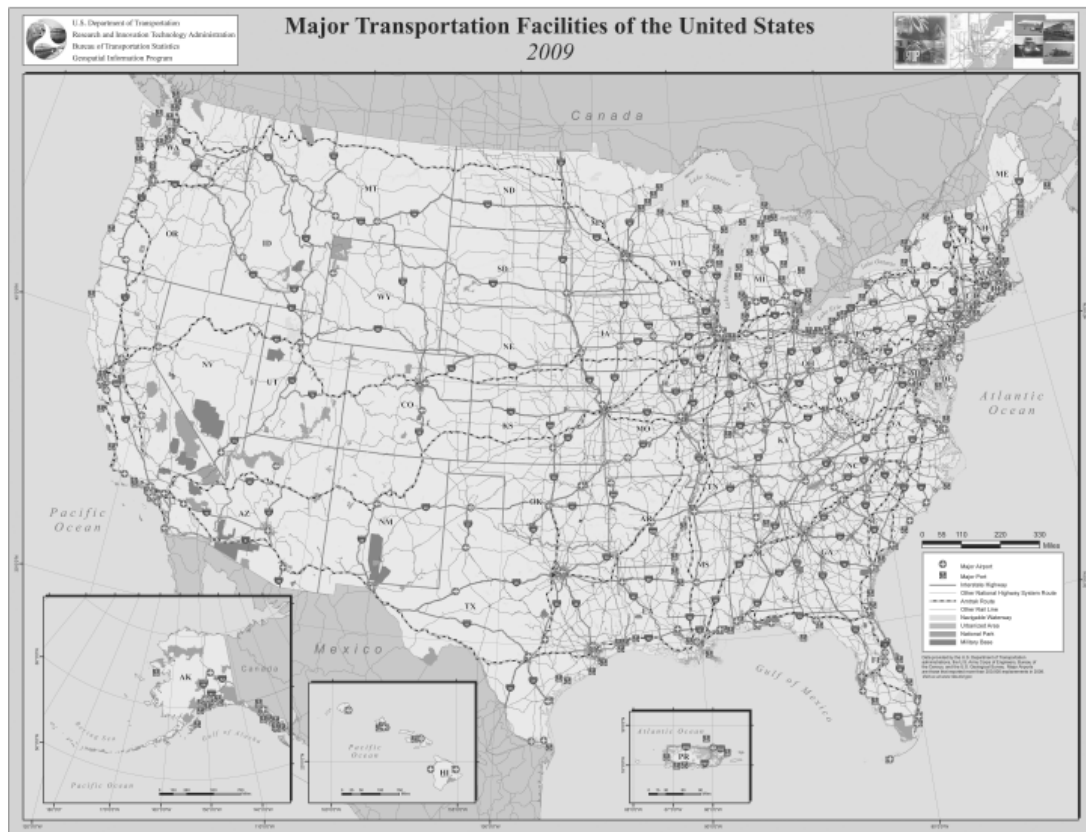
Table 15. Selected Leading U.S. Air All-Cargo, Rail, and Trucking Freight Carriers by Operating Revenues: 2005-2008
(Millions of \$)

Rank in 2008	Carrier	Mode	2005	2006	2007	2008
1	UPS	All-cargo	42,581	47,547	49,692	51,486
2	FedEx	All-cargo	32,294	35,241	37,953	35,497
3	BNSF Railway	Rail	12,987	14,985	15,802	18,018
4	Union Pacific Railroad	Rail	13,578	15,578	16,283	17,970
5	DHL USA ¹	All-cargo	9,991	16,384	14,322	14,994
6	CSX Transportation	Rail	8,618	9,566	10,030	11,255
7	Norfolk Southern	Rail	8,527	9,407	9,432	10,661
8	YRC Worldwide	Trucking	8,742	9,919	9,621	8,940
9	Ryder System	Trucking	5,741	6,307	6,566	6,204
10	Con-way	Trucking	4,116	4,221	4,387	5,037
11	Penske Truck Leasing	Trucking	4,000	4,000	4,100	4,000
12	J.B. Hunt Transport	Trucking	3,128	3,328	3,490	3,732
13	Schneider National	Trucking	3,400	3,700	3,400	3,700
14	Swift Transportation	Trucking	3,197	3,173	3,265	3,400
15	CEVA Logistics	Trucking	972	916	1,737	2,810
16	Sirva	Trucking	1,096	1,044	3,970	2,747
17	Landstar System	Trucking	2,518	2,514	2,487	2,643
18	Werner	Trucking	1,972	2,081	2,071	2,166
19	TransForce	Trucking	1,227	1,328	1,806	2,120
20	Pacer International	Trucking	1,860	1,888	1,969	2,088
21	UniGroup	Trucking	2,209	2,300	2,200	2,000
22	Kansas City Southern Railway	Rail	1,352	1,660	1,743	1,852
23	Arkansas Best	Trucking	1,860	1,860	1,837	1,833
24	U.S. Xpress	Trucking	1,164	1,472	1,598	1,826
25	Old Dominion Freight Line	Trucking	1,061	1,279	1,402	1,538
26	Estes Express Lines	Trucking	1,388	1,477	1,395	1,480
27	Purolator Courier	Trucking	1,036	997	1,349	1,464
28	Greatwide Logistics	Trucking	811	1,140	1,240	1,200
29	Crete Carrier	Trucking	926	1,004	995	1,110
30	Saia	Trucking	754	875	976	1,030

NOTE: Generally, detailed operating financial data for freight carriers are not available, particularly for privately owned companies.
¹ DHL USA ended its U.S. domestic services on Jan. 30, 2009 and focused its U.S. business on international services.

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from Transport Topics Online, available at ttnews.com/tt100 as of Sept. 25, 2009.
Association of American Railroads, available at www.aar.org as of Sept. 25, 2009.

U.S. Trends



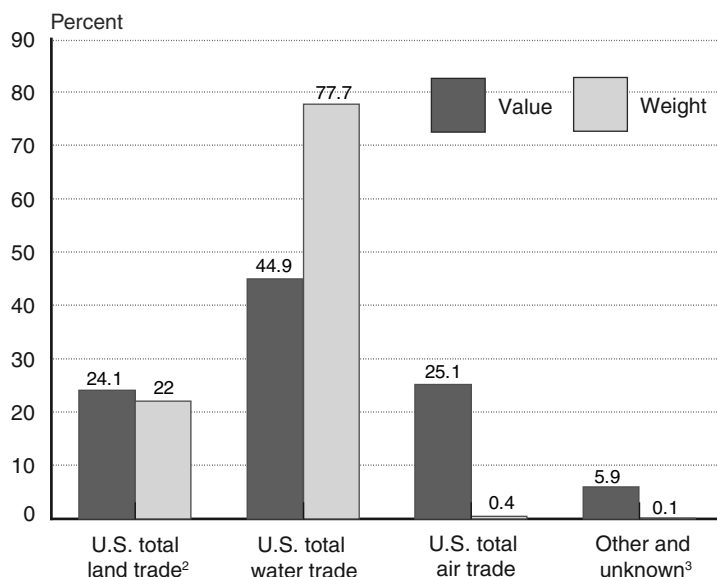
USDOT, RITA, BTS

In 2008, U.S. freight gateways handled more than \$3.4 trillion (in current dollars) of international merchandise trade. From 2007 to 2008, merchandise exports rose 12 percent, and imports rose 7 percent. Since 1990, the leading U.S. freight gateways have handled increasing volumes of freight as the movement of traded goods to and from the United States has expanded.

From 1990 to 2008, the value of U.S. international merchandise trade grew from \$889 billion to \$3.4 trillion, increasing at an average annual rate of 8 percent. In inflation-adjusted terms (using chained 2000 dollars), this trade grew about 7 percent per year, from \$837 billion to more than \$2.6 trillion. During this period, the growth in merchandise trade spurred the development of marine, air-cargo, and border-crossing facilities to connect domestic U.S. origins and destinations to markets abroad.

MODAL VIEW

Figure 10. Modal Shares of U.S. Merchandise Trade Handled by Land, Water, and Air Gateways by Value and Weight: 2007¹



¹ BTS estimated the export weight for truck, rail, pipeline, and other and unknown based on value-to-weight ratios from the import data. This estimation procedure was used because U.S. exporters are not currently required to report the export weight for land modes. Weight for water and air exports and imports are from U.S. Department of Commerce, U.S. Census Bureau.

² Includes truck, rail, and pipeline modes.

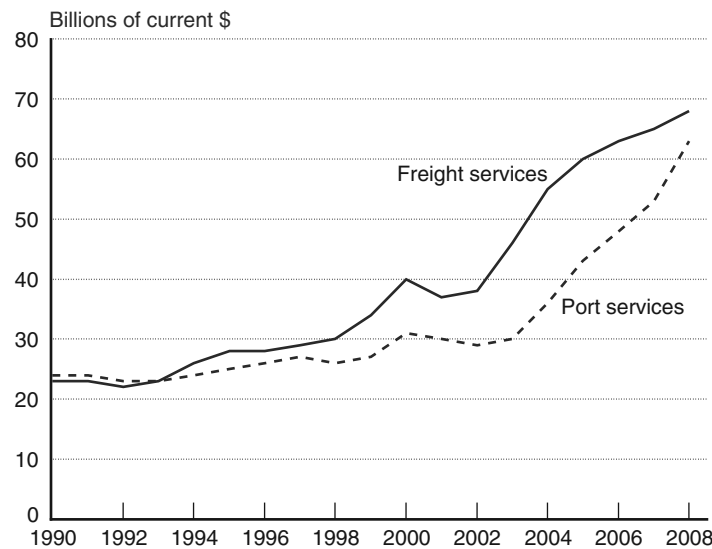
³ Includes purchased vehicles such as aircraft or boats moving from manufacturer to customer where the vehicle itself is the shipment, pedestrians carrying freight, and miscellaneous.

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **Value data—Water and air:** U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, FT920 U.S. Merchandise Trade: Selected Highlights, December 2007, available at www.census.gov/foreign-trade/Press-Release/ft920_index.html as of October 2008. **Truck, rail, pipeline, and other and unknown:** USDOT, RITA, BTS, Transborder Freight Data, October 2008. **Weight data—Water and air:** U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, FT920 U.S. Merchandise Trade: Selected Highlights, December 2007, available at www.census.gov/foreign-trade/Press-Release/ft920_index.html as of October 2008. **Truck, rail, pipeline, and other and unknown:** USDOT, RITA, BTS, Transborder Freight Data; and special calculation, October 2008.

- Nearly all shipments require the use of more than one mode of transportation to reach their final destinations. For example, a shipment of imported goods arriving at a maritime port is transferred to rail or truck to continue its journey. Railroads tend to carry commodities long distances at low prices, while trucks often carry commodities shorter distances and more quickly.
- Waterborne vessels account for more U.S. international trade, both in terms of tonnage and value, than any other mode—78 percent of the weight and 45 percent of the value of U.S. merchandise trade in 2007. Water transportation is less dominant in terms of value because high value-per-ton commodities often move by air and truck, particularly in U.S. trade with Canada and Mexico.
- Intermodal rail traffic—the transport of containers or truck trailers by rail—has significantly increased during the past two decades.

FREIGHT CARRIER AND PORT SERVICES

Figure 11. U.S. International Freight and Port Services Trade: 1990–2008



NOTE: Data cover total payments and receipts. Payments consist of money paid by domestic consumers to foreign carriers or service providers. Receipts consist of money received by domestic carriers or service providers from foreign sources.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from U.S. Department of Commerce, Bureau of Economic Analysis, U.S. International Transactions Accounts Data, available at www.bea.gov/international/bp_web/simple.cfm?anon=104324&table_id=22&area_id=3 as of Sept. 10, 2009.

- Freight carriers transport international cargo between the United States and its trading partners around the world. In addition to trade in merchandise, the United States buys (imports) and sells (exports) freight services via the various transportation modes. The freight and port services sector includes several industries, including carriers, ports, terminal operators, and third-party logistics providers, such as freight forwarders and consolidators.
- In 2008, U.S. trade in freight and port services was \$131 billion. Receipts for exports were \$59 billion, and payments for imports were \$72 billion. Of the \$131 billion, 52 percent (\$68 billion) was for freight services and the remainder was for port services.

Table 16. U.S. International Freight and Port Services Trade: 1990–2008
(Billions of current \$)

Year	Total		Freight services		Port services	
	Freight services	Port services	Receipts (exports)	Payments (imports)	Receipts (exports)	Payments (imports)
1990	23.4	23.6	8.4	15.0	13.7	9.9
1991	23.2	24.4	8.7	14.6	14.0	10.4
1992	22.0	23.3	8.4	13.6	13.1	10.2
1993	23.1	23.4	8.6	14.5	13.4	10.0
1994	25.6	24.2	9.6	16.0	14.2	10.0
1995	27.7	25.4	11.3	16.5	14.8	10.6
1996	27.7	25.8	11.1	16.5	14.9	10.9
1997	29.4	26.5	11.8	17.7	15.2	11.3
1998	30.5	25.5	11.0	19.4	14.6	11.0
1999	33.8	27.3	11.6	22.2	15.4	11.9
2000	39.9	31.3	12.5	27.4	17.3	14.0
2001	37.5	29.7	11.7	25.7	16.7	12.9
2002	38.3	29.3	12.3	26.0	16.9	12.4
2003	45.7	30.4	13.9	31.8	17.5	12.9
2004	54.7	36.4	15.5	39.2	21.5	14.9
2005	60.4	42.8	16.5	43.9	24.8	18.0
2006	63.2	48.4	17.4	45.7	28.8	19.6
2007	65.4	53.2	19.8	45.6	31.7	21.5
2008	67.7	63.4	22.4	45.2	36.5	26.9

NOTE: Payments consist of money paid by domestic consumers to foreign carriers or service providers. Receipts consist of money received by domestic carriers or service providers from foreign sources.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from U.S. Department of Commerce, Bureau of Economic Analysis, U.S. International Transactions Accounts Data, available at www.bea.gov as of Sept. 10, 2009.

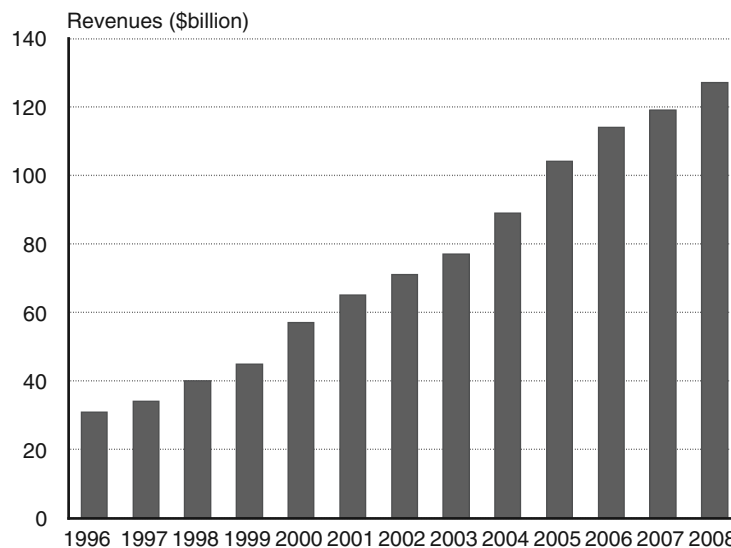
- In 2008, U.S. receipts for freight transportation services totaled \$22 billion, double the amount in 1998. Payments for freight services were \$45 billion, more than twice the amount in 1998.
- From 1998 to 2008, receipts and payments for port services more than doubled, to \$37 billion and \$27 billion respectively.

BOX A

U.S. THIRD-PARTY LOGISTICS PROVIDERS INDUSTRY

An important segment of the movement of U.S. international freight is the third-party logistics providers industry. The Council of Supply Chain Management Professionals defines third-party logistics (3PL) as the “outsourcing all or much of a company’s logistics operations to a specialized company.” Such outsourcing, allows shippers to focus on their core business activities while entrusting transportation, warehousing, customs-related, and other value-added activities to specialists able provide such services. In the United States, the use of 3PL providers by both large and small businesses has increased over time. Figure 12 shows the gross revenues of the U.S. 3PL industry from 1996 to 2008.

Figure 12. Gross Revenues of the U.S. Third-Party Logistics Providers Industry: 1996–2008



SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from Armstrong & Associates, Inc. 2009. U.S. and Global Third-Party Logistics Market Analysis. Available at http://3plogistics.com/PR_3PL_Financial-2009.htm as of Nov. 1, 2009.

Classification of 3PLs. The third-party logistics providers (3PL) industry could be categorized into asset-based and nonasset-based companies. Asset-based 3PLs own their own trucks and distribution centers. They are more suitable for large corporations requiring long-term contracts and value-added international transportation management services (Cain 2007). Asset-based 3PLs often work in conjunction with freight forwarders. Nonasset-based 3PLs do not own the vehicles or equipment used in providing their services. These firms are the majority of 3PLs. They contract with trucking companies, other carriers, and distribution centers for whatever they need to fulfill their services. This provides them more flexibility than the asset-based firms and they are able to offer expedited and customizable supply chain solutions. Nonasset-based

operators include air freight forwarders, truck freight brokers, intermodal marketing companies, and distribution entities (Cain 2007).

Outsourcing to 3PLs. Over the past decade, many companies have turned to outsourcing services not core to their line of business (Capgemini et. Al. 2009). Transportation and warehousing are the two most frequently outsourced activities. Table 17 summarizes the most common outsourced operations. Table 18 shows the leading global 3PL providers in 2008.

Table 17. Outsourced Logistics Services: 2008
(Percent of outsourced operations)

Logistics activity	All regions	North America	Europe	Asia Pacific	Latin America
Domestic transportation	86	75	92	95	80
International transportation	84	70	91	91	88
Customs brokerage	71	73	61	78	74
Warehousing	68	71	72	65	52
Forwarding	65	61	57	82	66
Cross-Docking	39	40	42	42	20
Product labeling, packaging, assembly, and kitting	38	33	42	40	34
Reverse logistics (defective, repair, return)	38	31	43	47	26
Freight bill auditing and payment	33	53	24	26	28
Transportation planning and management	32	32	33	34	20
Information technology services	30	28	34	30	26
Fleet management	22	14	26	28	15
Supply chain consultancy services provided by 3PLs	21	21	19	25	20
Customer service	13	10	13	15	14
Order entry, processing and fulfillment	13	12	8	20	15
LLP/4PL services	12	10	12	17	6

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on Capgemini, Georgia Institute of Technology, Oracle, and Panalpina, The State of Logistics Outsourcing, Results and Findings of the 14th Annual Study, 2009, available at 3plstudy.com as of Nov. 1, 2009.

Table 18. Top 15 Global Third-Party Logistics Providers: 2008

Providers	Gross revenues (millions)
DHL Supply Chain & Global Forwarding	37,100
DB Schenker Logistics	21,000
Kuehne & Nagel	20,087
Nippon Express	19,014
Panalpina	9,855
CEVA Logistics	9,304
UPS Supply Chain Solutions	9,055
C.H. Robinson Worldwide	8,579
DSV Solutions Holding A/S	7,094
Geodis	7,000
Agility	6,474
SDV International Logistics	5,851
Sinotrans	5,743
Expeditors Int'l of Washington	5,634
DACHSER GmbH & KG	5,292

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on Armstrong & Associates, Inc. A&A's Top 50 Global Third-Party Logistics Provider (3PL) List, available at 3plogistics.com as of Nov. 1, 2009.

Summary. Third-party logistics (3PL) providers are an important class of logistics intermediaries operating in the freight industry. These firms receive more than \$100 billion in revenues and make more than \$50 billion in payments to transportation carriers. While 3PLs are important to the freight industry, there is little information about the commodities they help transport and the value and tonnage of those commodities.

References

Cain, R. 2007. Are You Ready for a Third Party Logistics Provider?" *Multichannel Merchant*, Sept 26, 2007. Available at http://multichannelmerchant.com/opsandfulfillment/3PL_outsource/index.html.

Capgemini, Georgia Institute of Technology, Oracle, and Panalpina, The State of Logistics Outsourcing, Results and Findings of the 14th Annual Study, 2009. Available at <http://3plstudy.com/index.php?p=2009-3pl-study> as of Nov. 1, 2009.

Summary

There are dynamic industry-wide changes that continue to influence and shape the global freight industry as worldwide international trade is transformed by the global economy. The principal forces that are likely to affect future international merchandise trade and freight movements include the following:

- changes in U.S. reliance on imported consumer products,
- China's expanded role in the world economy and global trade,
- fluctuations in fuel prices and transportation costs,
- environmental concerns, and
- a rise in Internet shopping and on-demand deliveries.

These global forces and the pace of U.S. reliance on imported consumer products may affect the movement of freight from, to, and within the United States. Increased freight movements resulting from future resumption of growth in worldwide merchandise trade could affect U.S. freight gateways and the relative dominance of particular seaports, airports, and land border crossings.

PRINCIPAL FORCES OF CHANGE

Changes in U.S. reliance on imported consumer products. Like other leading world economies, the United States has seen its domestic economy shift from manufacturing and agriculture to an emphasis on service and information industries (USDOT FHWA 2007a). As the output of the U.S. information and service sectors expanded, American demand for consumer goods continued to increase steadily over the last two decades (Moran and McCully 2001). At the same time, U.S. businesses outsourced more parts and finished products from trading partners around the world. Together, those trends led the United States to rely more significantly on imports of consumer goods to meet growing domestic demand for manufactured products. A resumption of growth in U.S. demand for foreign consumer goods would spur an increase in international freight handled by U.S. gateways.

China's expanded role in the world economy and global trade. As the world's largest developing economy, China has emerged as a significant force in global trade. Since China opened its markets, its economic impact in the world has expanded rapidly. During the past two decades, China increased its industrial output and became the world's top manufacturer (CRS 2007). In 2008, China was the United States' second leading trading partner. China was also a top trading partner for the world's other developed economies, including Japan and the European Union. Continued growth in China's economic position, coupled with its continuing demand for raw materials and parts from around the world, will significantly fuel growth in global merchandise trade and freight movements.

Fluctuations in fuel prices and transportation costs. In 2007 and 2008, concerns about increased fuel prices and transportation costs emerged as oil price fluctuations seriously impacted freight carriers. When fuel prices rise, transportation costs become more important relative to the cost of inventory or shipping (Hummels 2009). If wide fluctuations in fuel prices continue in coming years, they could have the effect of reconfiguring global production, distribution, and freight transportation services. Significant fluctuations in world fuel prices could seriously affect the financial performance of freight carriers engaged in international trade, and could also change industry alliances and recent patterns of carrier cooperation.

Environmental concerns. While freight transportation is essential to continued economic growth, like other industrial activities it can have an unintended and negative impact on environmental quality (USDOT RITA BTS 2008). Some of the most prominent environmental concerns surrounding freight transportation include the following:

- *Climate change.* Transportation is the second-largest source of greenhouse gases, accounting for a significant proportion of the world's carbon dioxide emissions.
- *Pollution, water, and air quality.* Pollutants produced through the operation of the freight trucks—such as carbon monoxide, ozone, nitrogen oxide, and sulfur dioxide—contribute to climate change and harm human health. The use of larger maritime vessels increases the need for harbor dredging and increases the amount of ballast water produced, a factor that can help introduce nonindigenous aquatic species into waterways.
- *Land-use compatibility around maritime ports.* Increased port traffic exacerbates congestion on landside transportation systems, increasing vehicle delays and emissions.

Global and national actions aimed at mitigating these environmental impacts could potentially affect the worldwide freight industry in terms of future technology adoption, performance, and growth.

Rise in Internet shopping and on-demand deliveries. The continued popularity and acceptance of Internet shopping, coupled with increased adoption of just-in-time inventory management by shippers globally, has had an impact on how freight moves. Internet shopping requires carriers to deliver goods to end users rather than to intermediaries, resulting in overall growth in direct shipments to customers (USDOT FHWA 2007b). Together, these trends have increased the number of shipments, particularly small shipments, that carriers handle, and expanded the number of links in the freight supply chain that are needed to deliver goods to their final destination.

SUMMARY AND CONCLUSION

Globally, more than 8 billion tons of freight moved in international maritime and air transportation in 2008. A vast number of vessels, aircraft, and vehicles operated by several freight carriers moved these goods around the world. The major highlights of this report include the following:

- The majority of international freight transported worldwide comes from a few countries. In 2008, more than three-quarters of exported freight were from only 25 countries.

- From mid-2008 to mid-2009, as global economic activities slowed, goods transported worldwide by ocean carriers and airlines fell.
- Since 2001, U.S. shares of world GDP and exports have fallen as the share of developing Asian countries, particularly China, increased.
- Ocean carriers continue to transport the majority of internationally traded goods. During the past decade, worldwide containerized cargo grew faster than air cargo.
- In 2008, three U.S. seaports—South Louisiana, Houston, and New York/New Jersey—ranked 13th, 16th, and 21st, respectively among the world's top ports.
- Among the world's top container ports, Los Angeles, Long Beach, and New York/New Jersey ranked 16th, 17, and 20th, respectively.
- Among the world's top airports, Miami, Ted Stevens Anchorage, and John F. Kennedy ranked 10th, 12th, and 15th, respectively.

Changes in the global economic situation as well as trade between nations will continue to affect the choices of transportation modes used in transporting traded goods around the world and in the United States. Resumption of growth in worldwide merchandise trade is likely to create more demand for intermodal freight services. Continued integration of global economic activities and resumption of growth in oceanborne and air cargo would increase demand for freight transportation services.

Global economic activities will continue to shape where and how goods are produced and distributed. Expanded trade among countries will ultimately affect the movement of freight internationally as well as into and out of the United States. Fuel costs, changes in logistics supply chains, out-sourcing, just-in-time inventory management systems, and online shopping could impact the demand for freight transportation.

Supplemental Tables

Table A-1. World's Leading Economies by Gross Domestic Product: 1995, 2000, and 2008

Rank in 1995	Rank in 2000	Rank in 2008	Country	(Billions of current U.S. \$)			Share of global GDP (percent)		
				1995	2000	2008	1995	2000	2008
NA	NA	NA	World	29,633	31,972	60,863	100.0	100.0	100.0
1	1	1	United States	7,398	9,817	14,265	25.0	30.7	23.4
2	2	2	Japan	5,278	4,669	4,924	17.8	14.6	8.1
8	6	3	China	728	1,198	4,402	2.5	3.7	7.2
3	3	4	Germany	2,525	1,906	3,668	8.5	6.0	6.0
4	5	5	France	1,572	1,333	2,866	5.3	4.2	4.7
5	4	6	United Kingdom	1,157	1,481	2,674	3.9	4.6	4.4
6	7	7	Italy	1,127	1,101	2,314	3.8	3.4	3.8
17	19	8	Russia	313	260	1,677	1.1	0.8	2.8
9	11	9	Spain	597	582	1,612	2.0	1.8	2.6
7	9	10	Brazil	770	644	1,573	2.6	2.0	2.6
10	8	11	Canada	591	725	1,511	2.0	2.3	2.5
14	13	12	India	354	462	1,210	1.2	1.4	2.0
16	10	13	Mexico	314	629	1,088	1.1	2.0	1.8
13	14	14	Australia	371	390	1,011	1.3	1.2	1.7
11	12	15	South Korea	539	534	947	1.8	1.7	1.6
12	15	16	The Netherlands	419	386	869	1.4	1.2	1.4
23	18	17	Turkey	228	266	729	0.8	0.8	1.2
31	25	18	Poland	139	171	526	0.5	0.5	0.9
24	28	19	Indonesia	223	166	512	0.8	0.5	0.8
18	22	20	Belgium	276	233	506	0.9	0.7	0.8
15	20	21	Switzerland	316	250	493	1.1	0.8	0.8
21	21	22	Sweden	254	246	485	0.9	0.8	0.8
30	24	23	Saudi Arabia	142	189	482	0.5	0.6	0.8
28	27	24	Norway	149	169	456	0.5	0.5	0.7
22	23	25	Austria	239	192	415	0.8	0.6	0.7
19	16	26	Taiwan	274	321	393	0.9	1.0	0.6
33	31	27	Greece	129	128	358	0.4	0.4	0.6
37	39	28	Iran	91	96	345	0.3	0.3	0.6
25	29	29	Denmark	182	161	343	0.6	0.5	0.6
20	17	30	Argentina	258	284	326	0.9	0.9	0.5
40	35	31	Venezuela	77	117	319	0.3	0.4	0.5
27	30	32	South Africa	151	133	277	0.5	0.4	0.5
32	34	33	Finland	131	122	274	0.4	0.4	0.5
44	38	34	Ireland	67	97	273	0.2	0.3	0.4
26	33	35	Thailand	168	123	273	0.6	0.4	0.4
51	46	36	United Arab Emirates	41	70	260	0.1	0.2	0.4
34	36	37	Portugal	113	113	244	0.4	0.4	0.4
35	40	38	Colombia	104	94	241	0.4	0.3	0.4
38	41	39	Malaysia	90	94	222	0.3	0.3	0.4
47	47	40	Czech Republic	55	57	217	0.2	0.2	0.4
29	26	41	Hong Kong	144	169	216	0.5	0.5	0.4
54	53	42	Nigeria	37	46	214	0.1	0.1	0.4
36	32	43	Israel	96	124	202	0.3	0.4	0.3
56	56	44	Romania	35	37	200	0.1	0.1	0.3
39	42	45	Singapore	84	93	182	0.3	0.3	0.3
53	58	46	Ukraine	37	31	180	0.1	0.1	0.3
43	44	47	Chile	71	75	170	0.2	0.2	0.3
41	43	48	Philippines	76	76	169	0.3	0.2	0.3
42	45	49	Pakistan	74	74	168	0.2	0.2	0.3
46	37	50	Egypt	60	99	162	0.2	0.3	0.3

KEY: NA = Not applicable.

NOTE: Hong Kong is a special administrative region of China, but is separate from China in U.S. Foreign Trade Statistics.

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from International Monetary Fund, World Economic Outlook Database, April 2009, available at www.imf.org as of Sept. 14, 2009.

Table A-2. World's Top Merchandise Exporting Countries and their Exports to the United States: 2008
(Millions of U.S. \$)

Rank in 2008	Country	Total exports	Share of world total exports (percent)	Exports to United States	Exports to U.S. as share of country's total (percent)
	World	16,044,000	100.0	2,063,720	12.9
1	China	1,469,280	9.2	273,129	18.6
2	Germany	1,465,200	9.1	104,728	7.1
3	United States	1,300,190	8.1	NA	NA
4	Japan	783,149	4.9	139,022	17.8
5	The Netherlands	633,842	4.0	24,837	3.9
6	France	606,623	3.8	35,013	5.8
7	Italy	539,933	3.4	33,905	6.3
8	Belgium	477,159	3.0	23,095	4.8
9	United Kingdom	460,693	2.9	63,765	13.8
10	Canada	456,485	2.8	354,687	77.7
11	Russia	456,075	2.8	15,285	3.4
12	South Korea	426,763	2.7	46,501	10.9
13	Hong Kong	362,985	2.3	46,290	12.8
14	Singapore	339,414	2.1	24,196	7.1
15	Mexico	291,343	1.8	233,523	80.2
16	Saudi Arabia	285,928	1.8	51,823	18.1
17	Spain	267,581	1.7	11,229	4.2
18	Malaysia	224,490	1.4	28,321	12.6
19	Switzerland	200,065	1.2	19,221	9.6
20	Brazil	197,067	1.2	28,558	14.5
21	India	191,926	1.2	24,483	12.8
22	Australia	185,693	1.2	10,290	5.5
23	Sweden	184,000	1.1	12,091	6.6
24	Austria	181,737	1.1	7,802	4.3
25	Thailand	173,235	1.1	19,754	11.4
26	United Arab Emirates	170,126	1.1	1,225	0.7
27	Poland	169,074	1.1	2,481	1.5
28	Norway	167,976	1.0	7,499	4.5
29	Czech Republic	146,767	0.9	2,580	1.8
30	Indonesia	137,022	0.9	13,080	9.5
31	Turkey	132,311	0.8	4,398	3.3
32	Ireland	124,468	0.8	23,005	18.5
33	Denmark	116,974	0.7	6,223	5.3
34	Venezuela	115,648	0.7	47,828	41.4
35	Hungary	108,017	0.7	2,499	2.3
36	Iran	107,413	0.7	96	0.1
37	Finland	96,837	0.6	6,199	6.4
38	Nigeria	77,380	0.5	35,652	46.1
39	Algeria	76,642	0.5	18,211	23.8
40	Argentina	73,372	0.5	5,616	7.7
41	South Africa	73,005	0.5	8,083	11.1
42	Slovakia	71,047	0.4	1,212	1.7
43	Chile	71,011	0.4	7,856	11.1
44	Kuwait	67,382	0.4	6,727	10.0
45	Ukraine	66,884	0.4	1,949	2.9
46	Qatar	62,396	0.4	473	0.8
47	Angola	62,160	0.4	17,725	28.5
48	Israel	61,372	0.4	19,972	32.5
49	Vietnam	60,813	0.4	12,594	20.7
50	Libya	60,645	0.4	3,954	6.5
	Rest of the world	1,406,403	8.8	175,031	12.4

KEY: NA = Not applicable.

NOTE: Hong Kong is a special administrative region of China, but is separate from China in U.S. Foreign Trade Statistics.

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **United States**—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, available at www.census.gov, as of May 12, 2009. **World**—International Monetary Fund, Direction of Trade Statistics, available at www.imfstatistics.org as of Sept. 14, 2009.

Table A-3. World's Top Merchandise Importing Countries and Their Imports from the United States: 2008
(Millions of U.S. \$)

Rank in 2008	Country	Total imports	Share of world total imports (percent)	Imports from United States	Imports from U.S. as share of country's total (percent)
	World	16,708,900	100.0	1,340,520	8.0
1	United States	2,166,020	13.0	NA	NA
2	Germany	1,204,750	7.2	50,399	4.2
3	China	1,196,750	7.2	80,723	6.7
4	Japan	761,803	4.6	78,974	10.4
5	France	706,670	4.2	30,274	4.3
6	United Kingdom	634,542	3.8	55,192	8.7
7	The Netherlands	573,758	3.4	43,368	7.6
8	Italy	556,328	3.3	17,355	3.1
9	Belgium	470,194	2.8	26,112	5.6
10	Canada	449,077	2.7	235,479	52.4
11	South Korea	435,275	2.6	38,556	8.9
12	Spain	403,045	2.4	13,893	3.4
13	Hong Kong	388,947	2.3	19,541	5.0
14	Mexico	339,464	2.0	166,468	49.0
15	Singapore	319,779	1.9	37,853	11.8
16	India	304,166	1.8	20,533	6.8
17	Russia	274,284	1.6	12,204	4.4
18	Brazil	229,877	1.4	34,233	14.9
19	Australia	211,111	1.3	25,346	12.0
20	Poland	205,148	1.2	2,973	1.4
21	Turkey	201,964	1.2	11,977	5.9
22	United Arab Emirates	190,203	1.1	17,324	9.1
23	Austria	184,501	1.1	3,306	1.8
24	Switzerland	183,002	1.1	10,612	5.8
25	Malaysia	181,851	1.1	14,543	8.0
26	Thailand	178,526	1.1	11,375	6.4
27	Sweden	167,686	1.0	5,290	3.2
28	Czech Republic	141,703	0.8	1,709	1.2
29	Indonesia	129,274	0.8	7,898	6.1
30	Saudi Arabia	111,274	0.7	13,726	12.3
31	Denmark	111,199	0.7	3,355	3.0
32	Hungary	108,241	0.6	1,531	1.4
33	South Africa	99,561	0.6	7,817	7.9
34	Finland	92,108	0.6	1,849	2.0
35	Portugal	90,191	0.5	1,522	1.7
36	Norway	89,078	0.5	4,818	5.4
37	Ukraine	85,533	0.5	2,813	3.3
38	Vietnam	84,196	0.5	3,069	3.6
39	Ireland	83,758	0.5	9,689	11.6
40	Romania	82,995	0.5	1,207	1.5
41	Philippines	79,471	0.5	9,145	11.5
42	Greece	79,348	0.5	2,325	2.9
43	Slovakia	73,442	0.4	459	0.6
44	Iran	69,374	0.4	752	1.1
45	Israel	65,155	0.4	8,034	12.3
46	Egypt	63,431	0.4	6,634	10.5
47	Venezuela	56,984	0.3	13,872	24.3
48	Chile	55,960	0.3	10,689	19.1
49	Nigeria	54,519	0.3	4,512	8.3
50	Argentina	54,033	0.3	8,292	15.3
	Rest of the world	1,629,351	9.8	150,900	9.3

KEY: NA = Not applicable.

NOTE: Hong Kong is a special administrative region of China, but is separate from China in U.S. Foreign Trade Statistics.

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **United States**—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, available at www.census.gov as of May 12, 2009. **World**—International Monetary Fund, Direction of Trade Statistics, available at www.imfstatistics.org as of Sept. 14, 2009.

Table A-4. Value and Modal Shares of U.S. International Merchandise Exports by Major Trading Partners: 2008

Country	Millions of current U.S. \$				Modal shares (percent)		
	Total	Vessel	Air	Land, other, and unknown	Vessel	Air	Land, other, and unknown
World total	1,300,532	471,331	388,922	427,189	36.2	29.9	32.8
Canada	261,150	7,708	18,356	235,086	3.0	7.0	90.0
Mexico	151,220	14,919	7,007	129,294	9.9	4.6	85.5
China	69,733	44,735	21,170	3,828	64.2	30.4	5.5
Japan	65,142	33,328	27,918	3,896	51.2	42.9	6.0
Germany	54,505	21,930	28,124	4,452	40.2	51.6	8.2
United Kingdom	53,599	14,421	33,813	5,365	26.9	63.1	10.0
The Netherlands	39,719	19,745	18,070	1,905	49.7	45.5	4.8
South Korea	34,669	19,288	13,468	1,913	55.6	38.8	5.5
Brazil	32,299	17,596	12,955	1,748	54.5	40.1	5.4
Belgium	28,903	15,777	11,276	1,850	54.6	39.0	6.4
France	28,840	7,529	18,702	2,609	26.1	64.8	9.0
Singapore	27,854	10,167	15,739	1,947	36.5	56.5	7.0
Taiwan	24,926	11,070	12,852	1,005	44.4	51.6	4.0
Australia	22,219	12,547	7,982	1,689	56.5	35.9	7.6
Switzerland	22,024	1,319	19,409	1,296	6.0	88.1	5.9
Hong Kong	21,499	6,570	13,669	1,260	30.6	63.6	5.9
India	17,682	9,232	6,724	1,726	52.2	38.0	9.8
Italy	15,461	6,975	7,696	790	45.1	49.8	5.1
Israel	14,487	3,903	9,419	1,165	26.9	65.0	8.0
United Arab Emirates	14,417	7,423	4,350	2,644	51.5	30.2	18.3
Malaysia	12,949	3,084	9,481	384	23.8	73.2	3.0
Venezuela	12,610	9,764	2,402	444	77.4	19.0	3.5
Saudi Arabia	12,484	9,608	2,565	311	77.0	20.5	2.5
Spain	12,190	6,338	4,863	989	52.0	39.9	8.1
Chile	11,857	9,015	1,978	864	76.0	16.7	7.3
Colombia	11,437	7,945	3,164	328	69.5	27.7	2.9
Turkey	9,959	7,261	1,696	1,001	72.9	17.0	10.1
Russia	9,335	7,124	1,525	686	76.3	16.3	7.3
Thailand	9,067	4,489	4,336	241	49.5	47.8	2.7
Philippines	8,295	2,978	5,098	219	35.9	61.5	2.6
Ireland	7,611	1,451	4,635	1,525	19.1	60.9	20.0
Argentina	7,536	5,095	2,167	273	67.6	28.8	3.6
Dominican Republic	6,594	5,399	1,052	143	81.9	16.0	2.2
South Africa	6,490	4,099	1,997	394	63.1	30.8	6.1
Peru	6,183	4,854	1,162	166	78.5	18.8	2.7
Egypt	6,002	5,141	650	211	85.7	10.8	3.5
Costa Rica	5,680	3,225	2,165	290	56.8	38.1	5.1
Indonesia	5,644	4,433	720	492	78.5	12.8	8.7
Sweden	5,018	2,038	2,382	599	40.6	47.5	11.9
Panama	4,887	4,049	518	321	82.9	10.6	6.6
Honduras	4,846	4,295	248	304	88.6	5.1	6.3
Guatemala	4,718	3,996	457	265	84.7	9.7	5.6
Poland	4,131	1,912	941	1,277	46.3	22.8	30.9
Nigeria	4,102	3,542	490	70	86.3	11.9	1.7
Finland	3,761	2,537	898	326	67.5	23.9	8.7
Ecuador	3,450	2,651	684	115	76.8	19.8	3.3
Norway	3,292	1,103	1,573	616	33.5	47.8	18.7
The Netherlands Antilles	2,952	2,020	599	332	68.4	20.3	11.3
Vietnam	2,789	2,167	576	47	77.7	20.7	1.7
Bahamas	2,760	2,360	95	304	85.5	3.5	11.0

NOTE: Hong Kong is a special administrative region of China, but is separate from China in U.S. Foreign Trade Statistics.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, special tabulation, Sept. 14, 2009.

Table A-5. Value and Modal Shares of U.S. International Merchandise Imports by Major Trading Partners: 2008

Country	Millions of current U.S. \$				Modal shares (percent)		
	Total	Vessel	Air	Land, other, and unknown	Vessel	Air	Land, other, and unknown
World total	2,100,129	1,152,481	416,688	530,961	54.9	19.8	25.3
Canada	339,491	24,326	10,099	305,066	7.2	3.0	89.9
China	337,773	250,796	74,102	12,874	74.2	21.9	3.8
Mexico	215,942	46,504	5,952	163,486	21.5	2.8	75.7
Japan	139,262	102,928	32,944	3,390	73.9	23.7	2.4
Germany	97,497	57,163	31,821	8,512	58.6	32.6	8.7
United Kingdom	58,587	26,415	27,484	4,689	45.1	46.9	8.0
Saudi Arabia	54,747	54,124	48	576	98.9	0.1	1.1
Venezuela	51,424	51,118	74	232	99.4	0.1	0.5
South Korea	48,069	30,358	16,431	1,281	63.2	34.2	2.7
France	44,049	18,168	19,500	6,382	41.2	44.3	14.5
Nigeria	38,068	37,774	16	278	99.2	0.0	0.7
Taiwan	36,326	21,975	12,838	1,514	60.5	35.3	4.2
Italy	36,135	20,541	12,833	2,761	56.8	35.5	7.6
Ireland	31,346	4,606	25,503	1,237	14.7	81.4	3.9
Malaysia	30,736	10,072	19,000	1,664	32.8	61.8	5.4
Brazil	30,453	25,976	1,884	2,593	85.3	6.2	8.5
Russia	26,783	24,459	2,049	275	91.3	7.6	1.0
India	25,704	16,029	9,274	402	62.4	36.1	1.6
Thailand	23,538	13,750	8,651	1,137	58.4	36.8	4.8
Israel	22,336	4,232	16,773	1,330	18.9	75.1	6.0
Iraq	22,080	21,167	159	754	95.9	0.7	3.4
The Netherlands	21,123	13,154	6,758	1,211	62.3	32.0	5.7
Algeria	19,355	19,226	12	116	99.3	0.1	0.6
Angola	18,911	18,875	37	0	99.8	0.2	0.0
Switzerland	17,782	3,856	12,730	1,195	21.7	71.6	6.7
Belgium	17,308	7,485	9,163	661	43.2	52.9	3.8
Singapore	15,885	3,957	10,798	1,130	24.9	68.0	7.1
Indonesia	15,799	13,755	1,858	187	87.1	11.8	1.2
Colombia	13,093	10,768	1,480	845	82.2	11.3	6.5
Vietnam	12,901	11,661	991	248	90.4	7.7	1.9
Sweden	12,498	6,856	4,789	853	54.9	38.3	6.8
Spain	11,094	7,939	2,607	547	71.6	23.5	4.9
Australia	10,589	7,987	2,225	377	75.4	21.0	3.6
South Africa	9,948	5,415	4,425	108	54.4	44.5	1.1
Ecuador	9,048	8,555	267	226	94.5	3.0	2.5
Trinidad and Tobago	9,030	8,934	53	43	98.9	0.6	0.5
Philippines	8,713	4,822	3,634	257	55.3	41.7	2.9
Austria	8,457	5,039	2,755	663	59.6	32.6	7.8
Chile	8,196	6,725	1,392	80	82.0	17.0	1.0
Norway	7,315	5,808	1,326	181	79.4	18.1	2.5
Kuwait	7,093	7,057	21	14	99.5	0.3	0.2
Hong Kong	6,483	3,398	2,641	444	52.4	40.7	6.9
Denmark	6,446	3,361	2,429	657	52.1	37.7	10.2
Finland	5,903	4,354	1,148	402	73.7	19.4	6.8
Argentina	5,822	5,453	312	58	93.7	5.4	1.0
Peru	5,812	4,567	1,209	37	78.6	20.8	0.6
Republic of Congo	5,074	5,060	12	2	99.7	0.2	0.0
Turkey	4,642	3,685	816	141	79.4	17.6	3.0
Azerbaijan	4,361	4,329	3	29	99.3	0.1	0.7
Libya	4,179	4,094	2	83	98.0	0.1	2.0

NOTE: Hong Kong is a special administrative region of China, but is separate from China in U.S. Foreign Trade Statistics.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, special tabulation, Sept. 14, 2009.

Table A-6. World and United States International Merchandise Trade: 1990–2008

Year	World (billions of current U.S. \$)		United States (billions of current U.S. \$)	
	Exports	Imports	Exports	Imports
1990	3,383	3,517	394	495
1991	3,494	3,636	422	488
1992	3,749	3,895	448	533
1993	3,723	3,796	465	581
1994	4,258	4,321	513	663
1995	5,083	5,146	585	744
1996	5,305	5,391	625	795
1997	5,530	5,598	689	870
1998	5,400	5,526	682	912
1999	5,667	5,821	696	1,025
2000	6,388	6,593	782	1,218
2001	6,141	6,381	729	1,141
2002	6,435	6,629	693	1,161
2003	7,518	7,748	725	1,257
2004	9,133	9,486	819	1,470
2005	10,363	10,759	906	1,673
2006	11,969	12,364	1,037	1,854
2007	13,849	14,342	1,162	1,957
2008	16,044	16,709	1,301	2,100
Percent change, 1990–2008	374.2	375.0	230.4	324.0
Average annual growth rate, 1990–2008	9.0	9.0	6.9	8.4

SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources.

United States—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, available at www.census.gov, as of May 12, 2009.

World—International Monetary Fund, Direction of Trade Statistics, available at www.imfstatistics.org as of Sept. 14, 2009.

Table A-7. Trends in World and U.S. Air Revenue Freight for Total and International Services: 1995–2008

Year	World carriers' freight		U.S. carriers' freight	
	Tons (thousands)	Revenue ton-kilometers (millions)	Tons (thousands)	Revenue ton-kilometers (millions)
Total air cargo				
1995	22,189	83,130	4,352	30,228
1996	23,234	89,200	4,575	32,171
1997	26,360	102,880	5,072	35,521
1998	26,496	101,820	4,995	36,322
1999	28,103	108,660	4,936	37,462
2000	30,370	118,080	5,360	38,867
2001	28,829	110,800	7,634	38,661
2002	31,420	119,840	10,218	41,245
2003	33,522	125,760	16,257	46,593
2004	36,661	139,040	17,507	53,038
2005	37,638	142,520	17,274	54,991
2006	39,822	151,230	17,375	55,653
2007	41,774	158,280	17,369	55,975
2008	40,505	156,310	15,837	51,897
International segment air cargo				
1995	12,994	70 340	2,662	15,080
1996	13,587	75 510	2,974	16,603
1997	15,690	87 740	3,476	19,430
1998	16,005	87 050	3,498	19,542
1999	17,262	93 280	3,443	20,305
2000	18,800	101 560	3,746	21,383
2001	18,014	95 950	3,511	20,034
2002	18,808	101 590	3,769	23,122
2003	19,678	103 130	3,665	26,021
2004	21,796	115 120	4,114	30,188
2005	22,630	118,440	4,453	33,085
2006	23,900	125,700	4,647	34,221
2007	25,200	132,140	4,752	34,690
2008	25,000	130,890	4,398	32,635

NOTE: The U.S. data were converted from short ton-miles to ton-kilometers. To convert short ton-miles to metric ton-kilometers, first multiply by 1.61 (for kilometers) and then divide by 1.1 (for metric tons).

SOURCES: U.S. Department of Transportation (USDOT), Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics (BTS), based on data from various sources. **World**—International Civil Aviation Organization (ICAO), special tabulations, Sept. 28, 2009. **United States**—USDOT, RITA, BTS, Office of Airline Information, TranStats. Tonnage—T100-Segment data (U.S. carriers only). Ton-kilometers—T2-U.S. Air Carrier Traffic and Capacity Statistics, available at www.bts.gov as of Sept. 29, 2009.

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Clean Cities Alternative Fuel Price Report

October 2013



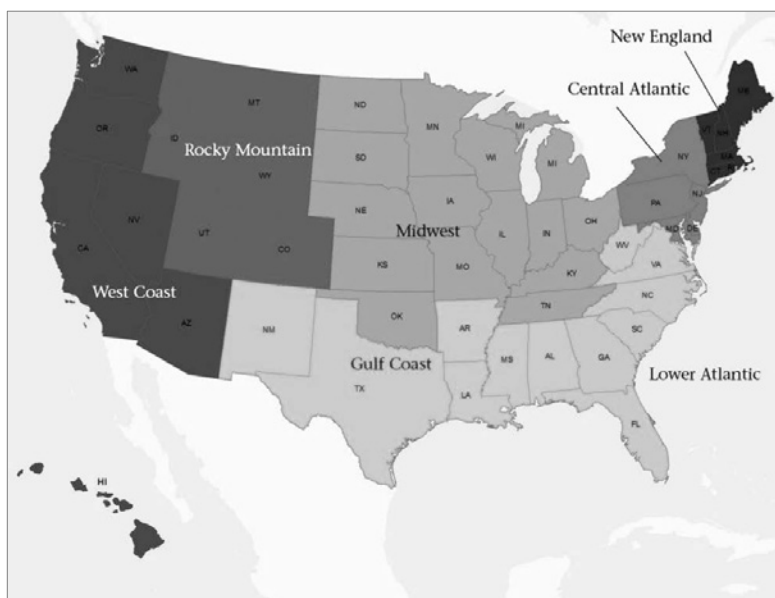
U. S. Department of Energy

WELCOME!

Welcome to the October 2013 issue of the Clean Cities Alternative Fuel Price Report, a quarterly report designed to keep Clean Cities coalitions and other interested parties up to date on the prices of alternative and conventional fuels in the United States. This issue summarizes prices that were collected between October 4, 2013 and October 18, 2013 from Clean Cities Coordinators, fuel providers, and other Clean Cities stakeholders.

METHODOLOGY

In order to collect price information for both alternative and conventional fuels from areas across the country, Clean Cities coordinators, fuel providers, and other key stakeholders were requested to provide prices for fuels in their areas on a voluntary basis. Prices were collected on all major alternative fuels currently in widespread use (natural gas, propane, biodiesel, and ethanol), as well as prices for conventional fuels at stations that also sell alternative fuels (or stations nearby). Prices were collected from public and private refueling stations throughout the country between October 4, 2013 and October 18, 2013. Prices were then averaged to determine regional price trends by fuel and variability in fuel price within and among regions.¹ Consistent with the fuel price reporting format the U.S. Energy Information Administration (EIA) uses, prices in this report are grouped by the Petroleum Administration for Defense Districts (PADD); the districts are illustrated in the map to the right.



This report's prices represent retail, at-the-pump sales prices for each fuel, including federal and state motor fuel taxes. In some cases, prices were collected from government or utility refueling facilities and these taxes were not included in the prices reported to Clean Cities. In these instances, although these users are not required to pay these taxes, the appropriate federal and state taxes were added to the reported prices to provide a more representative basis for comparison. In some cases, states may charge a flat annual fee for state motor fuel taxes, especially for gaseous fuels like compressed natural gas (CNG) and liquefied petroleum gas (LPG or propane). These flat fees are not considered in the prices reported in these pages.

¹ Fuel price averages for this report are determined by simply averaging the individual data points received. A comparison of average fuel prices for private and for public stations by region can be found on pages 13-14.

SUMMARY OF CURRENT REPORT INFORMATION

Table 1 shows overall nationwide average prices for conventional and alternative fuels.² As this table illustrates, alternative fuel prices relative to conventional fuels vary, with some (B20, B99-B100) higher and some (CNG, E85 and propane) lower. On an energy-equivalent basis, CNG is about \$1.36 less than gasoline. On a per-gallon basis, E85 is about 41 cents less than gasoline, and propane is about 49 cents less than gasoline. B20 prices are higher than regular diesel by about 11 cents, while B99/B100 blends have a cost of about 27 cents per gallon more than regular diesel.³

Table 1. Overall Average Fuel Prices

	Nationwide Average Price for Fuel This Report	Nationwide Average Price for Fuel Last Report	Change in Price This Report vs. Last Report	Units of Measurement
Gasoline (Regular)	\$3.45	\$3.65	(\$0.20)	per gallon
Diesel	\$3.91	\$3.91	\$0.00	per gallon
CNG	\$2.09	\$2.14	(\$0.05)	per GGE
Ethanol (E85)	\$3.04	\$3.23	(\$0.19)	per gallon
Propane	\$2.96	\$2.73	\$0.23	per gallon
Biodiesel (B20)	\$4.02	\$3.89	\$0.13	per gallon
Biodiesel (B99-B100)	\$4.18	\$4.19	(\$0.01)	per gallon

Relative to the last report from July 2013, the average prices for most of the liquid fuels have decreased by as much as 20 cents, while B20 increased by 13 cents. The gaseous fuel prices experienced a decrease of 5 cents for CNG and an increase of 23 cents for propane. It should be noted that the price changes occur as a result of a number of factors, including an actual change in price, a slightly differing sample of prices (both location and quantity), and seasonal variations of demand.

Prices in this report were collected and are reported in the units in which they are typically sold (dollars per gallon or dollars per gasoline gallon equivalent). Because these fuels have differing energy contents per gallon, the price paid per unit of energy content can differ somewhat from the price paid per gallon. Table 2 shows the fuel prices from Table 1 for the current reporting period normalized to a price per gasoline gallon equivalent (GGE), per diesel gallon equivalent (DGE), or per million British thermal units (BTUs) of energy. This calculation uses the nominal lower heating values in BTUs per gallon of fuel from the Oak Ridge National Laboratory's Transportation Energy Data Book.⁴ Prices for the alternative fuels in terms of price per gallon equivalent are generally higher than their price per gallon because of their lower energy content per gallon.⁵ However, consumer interest in alternative fuels generally increases when the alternative fuel price is less than the conventional fuel price and as the price differential per gallon increases, even if that differential does not directly translate to savings on an energy-equivalent basis.

Table 2. October 2013 Overall Average Fuel Prices on Energy-Equivalent Basis

	Nationwide Average Price in Gasoline Gallon Equivalents	Nationwide Average Price in Diesel Gallon Equivalents	Nationwide Average Price in Dollars per Million Btu
Gasoline	\$3.45	\$3.84	\$29.85
Diesel	\$3.51	\$3.91	\$30.39
CNG	\$2.09	\$2.33	\$18.07
Ethanol (E85)	\$4.30	\$4.80	\$37.29
Propane	\$4.09	\$4.56	\$35.46
Biodiesel (B20)	\$3.67	\$4.09	\$31.79
Biodiesel (B99-B100)	\$4.12	\$4.59	\$35.70

² A very small sample (5 points) of hydrogen information was received: One of the five locations for which data was received reported hydrogen at zero cost for vehicle use, with an average price for the four other hydrogen stations of \$2.77 per gasoline gallon equivalent.

³ ASTM specifications now include blends of up to 5% biodiesel as regular diesel fuel; therefore the separate listing for B2/B5 was discontinued as of October 2009.

⁴ A listing of the conversion factors used appears as an appendix at the end of this report.

⁵ For ethanol flexible-fuel vehicles (FFVs), the actual difference in fuel used per mile is somewhat less than would be calculated simply on the difference in energy content of the fuels, as some sources have noted that some FFVs can achieve better energy efficiency (miles per unit of energy) on E85 than on gasoline. This effect is not currently included in these calculations as the magnitude of the effect varies by specific FFV model.

GASOLINE AND DIESEL PRICES

Table 3 shows average prices for gasoline and diesel as collected by Clean Cities coordinators and other stakeholders (supplemented where necessary with other EIA reference sources for conventional fuels). These prices were collected from refueling stations selling both conventional fuels and alternative fuels, and from conventional refueling stations near alternative fuel stations. There were 516 price points collected for gasoline and 350 for diesel. The average price for gasoline ranged from a low of \$3.11 per gallon in the Gulf Coast region to a high of \$3.78 per gallon in the West Coast region. Diesel prices ranged from \$3.78 per gallon in the Central Atlantic and Gulf Coast regions to \$4.11 per gallon in the West Coast region. Because prices for conventional fuels were collected from stations and regions providing alternative fuel price information, data collection was not uniform across the regions of the country. However, the information is representative of refueling stations selling both alternative fuels and conventional fuels.

Table 4 shows average prices as provided by EIA on the petroleum information section of its website.⁶ These prices are averages of prices from a selection of 900 gasoline and 350 diesel retail fuel stations across the country. Note that EIA's average nationwide prices match relatively closely with the average prices reported by Clean Cities stakeholders. Prices differed by 10 cents or less for gasoline and 6 cents or less for diesel in each region on a per gallon basis, with the exceptions of New England, where EIA average prices for gasoline differed by 23 cents, and the Central Atlantic, where EIA average prices for diesel differed by 18 cents from the average prices reported by Clean Cities stakeholders. Comparisons in this document between conventional and alternative fuel prices will be made using prices collected from Clean Cities sources wherever possible, as these prices are most representative of stations selling both conventional and alternative fuels.

Table 3. Average Gasoline and Diesel Prices by Region from Clean Cities Sources

	Regular Gasoline Information Reported by Clean Cities (\$/gal)		Diesel Information Reported by Clean Cities (\$/gal)	
	Average Price	Number of Data Points	Average Price	Number of Data Points
New England	\$3.76	27	\$4.09	33
Central Atlantic	\$3.41	54	\$3.78	47
Lower Atlantic	\$3.34	62	\$3.83	42
Midwest	\$3.32	138	\$3.81	87
Gulf Coast	\$3.11	40	\$3.78	18
Rocky Mountain	\$3.42	94	\$3.89	45
West Coast	\$3.78	101	\$4.11	78
NATIONAL AVERAGE	\$3.45	516	\$3.91	350

Table 4. EIA Gasoline and Diesel Price Averages

	Gasoline Average Price from EIA, Week of 10/14/13	Diesel Average Price from EIA, Week 10/14/13
New England	\$3.53	\$4.03
Central Atlantic	\$3.40	\$3.96
Lower Atlantic	\$3.26	\$3.84
Midwest	\$3.30	\$3.85
Gulf Coast	\$3.11	\$3.80
Rocky Mountain	\$3.46	\$3.89
West Coast	\$3.68	\$4.05
NATIONAL AVERAGE	\$3.35	\$3.89

⁶ <http://www.eia.doe.gov/petroleum/>

COMPRESSED NATURAL GAS (RELATIVE TO GASOLINE)

Table 5 shows average prices for compressed natural gas (CNG) for vehicle use, grouped by region, as well as regular gasoline prices, as provided by Clean Cities representatives. These prices were collected from across the country from Clean Cities coordinators, fuel providers, and other stakeholders on a voluntary basis.

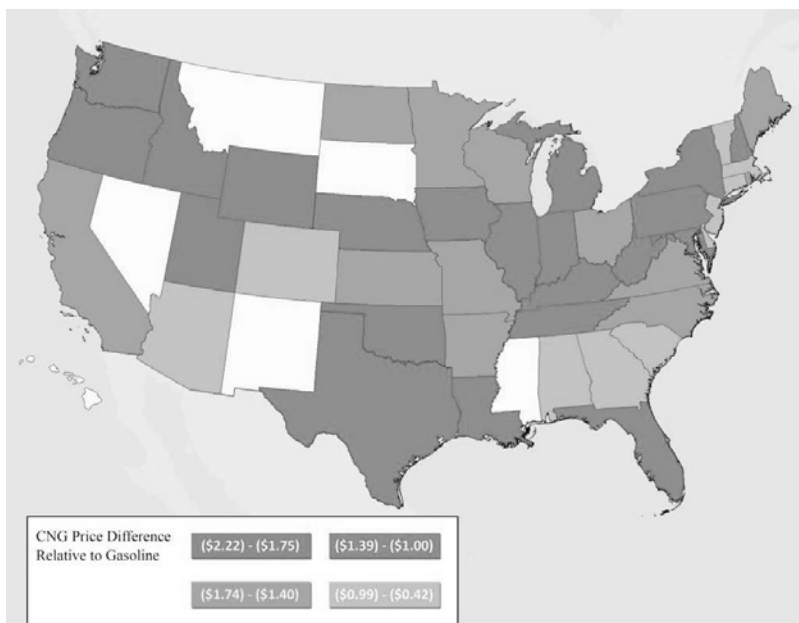
As Table 5 illustrates, CNG has a lower average price than gasoline for all regions of the country, with the largest difference (\$1.60 per GGE) being in the Rocky Mountain region. On average, CNG costs about \$1.36 less than gasoline on a per gasoline gallon equivalent basis.

The map to the right illustrates price differentials by state for natural gas relative to gasoline, based on differentials between natural gas and gasoline prices for each state (as opposed to the regional averages illustrated in Table 5). In this map, negative numbers represent prices for CNG lower than gasoline. As the map illustrates, CNG prices (per GGE) were favorable relative to gasoline in all states for which pricing data was reported, with the most favorable pricing found in states located in the Rocky Mountain, Midwest and West Coast regions.

Tech Note: Prices for CNG were provided by the individual stakeholders in gasoline gallon equivalents from the "price at the pump." It should be noted that the internal conversion factor between the physical quantities of gas delivered and gasoline gallon equivalent was not collected from each of the refueling stations. Regional differences in gas heat content relative to the internal pump conversion factor may change the price per gasoline gallon equivalent, but this report did not determine these differences.

Table 5. Compressed Natural Gas Average Prices by Region from Clean Cities Sources

	Natural Gas (CNG) Information Reported by Clean Cities (\$/GGE)		Regular Gasoline Information Reported by Clean Cities (\$/gal)	
	Average Price	Number of Data Points	Average Price	Number of Data Points
New England	\$2.53	28	\$3.76	27
Central Atlantic	\$2.19	104	\$3.41	54
Lower Atlantic	\$2.06	27	\$3.34	62
Midwest	\$1.87	72	\$3.32	138
Gulf Coast	\$2.02	29	\$3.11	40
Rocky Mountain	\$1.82	106	\$3.42	94
West Coast	\$2.31	103	\$3.78	101
NATIONAL AVERAGE	\$2.09	469	\$3.45	516



COMPRESSED NATURAL GAS (RELATIVE TO DIESEL)⁷

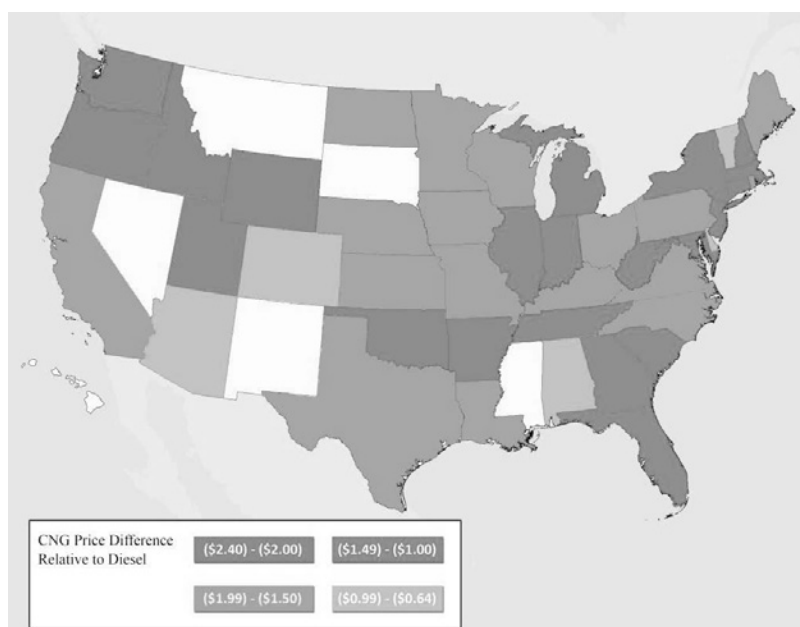
Table 6 shows average prices for compressed natural gas (CNG) for vehicle use, grouped by region, as well as conventional diesel fuel prices, as provided by Clean Cities representatives and supplemental sources. These prices were collected from across the country from Clean Cities coordinators, fuel providers, and other stakeholders on a voluntary basis. The CNG prices in Table 6 are based upon the same group of prices as for Table 5, but converted to a cost per diesel gallon equivalent basis instead of a cost per gasoline gallon equivalent, to compare directly with diesel prices.

Table 6. Compressed Natural Gas Average Prices by Region from Clean Cities Sources

	Natural Gas (CNG) Information Reported by Clean Cities (\$/DGE)		Diesel Information Reported by Clean Cities (\$/gal)	
	Average Price	Number of Data Points	Average Price	Number of Data Points
New England	\$2.82	28	\$4.09	33
Central Atlantic	\$2.44	104	\$3.78	47
Lower Atlantic	\$2.3	27	\$3.83	42
Midwest	\$2.09	72	\$3.81	87
Gulf Coast	\$2.25	29	\$3.78	18
Rocky Mountain	\$2.03	106	\$3.89	45
West Coast	\$2.57	103	\$4.11	78
NATIONAL AVERAGE	\$2.33	469	\$3.91	350

As Table 6 illustrates, CNG has a lower average price than diesel for all regions of the country, with the largest difference (\$1.86 per DGE) being in the Rocky Mountain region. On average, CNG costs about \$1.58 less than diesel on a per diesel gallon equivalent basis.

The map to the right illustrates price differentials by state for CNG relative to diesel, based on differentials between CNG prices and diesel prices for each state (as opposed to the regional averages illustrated in Table 6). In this map, negative numbers represent prices for CNG lower than prices for diesel. States not highlighted with a color did not have any CNG data points in the current report. As with the comparison to gasoline, CNG prices relative to diesel were favorable for all states for which pricing data was reported, with the most favorable pricing found in states located in the Rocky Mountain, Midwest and West Coast regions.



⁷ A total of 19 liquefied natural gas (LNG) price points were collected with an average fuel price of \$2.34 per gallon, or \$4.03 per DGE. Because of the small number of price points, this data is not reflected in the report.

ETHANOL (E85)

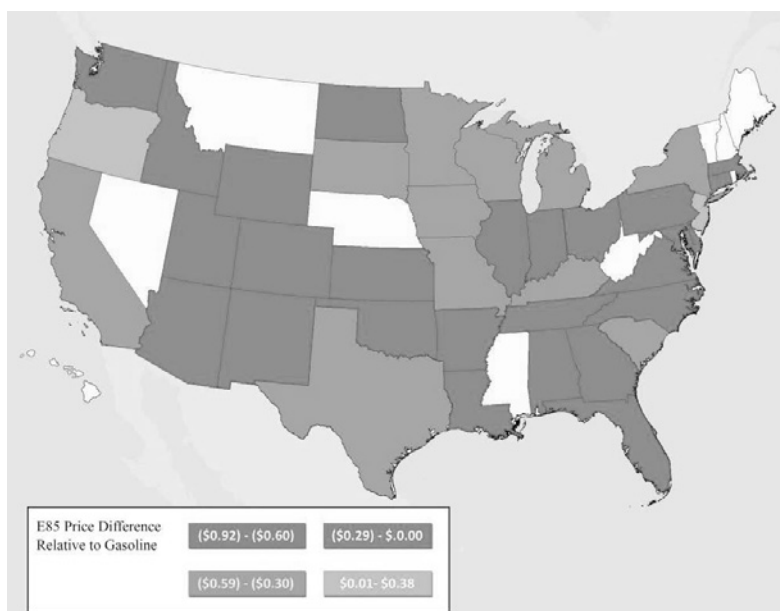
Table 7 shows average prices for an 85% ethanol/15% gasoline (E85) fuel blend, grouped by region, as well as regular gasoline prices, as provided by Clean Cities representatives. These prices were collected from across the country from Clean Cities coordinators, fuel providers, and other stakeholders on a voluntary basis.

As Table 7 illustrates, E85 has a lower average price per gallon than regular gasoline for each region, with the largest average differential (51 cents) being found in the West Coast region. On average, E85 is about 41 cents lower in price than regular gasoline on a per-gallon basis.

Table 7. Ethanol (E85) Average Prices by Region from Clean Cities Sources

	Ethanol (E85) Information Reported by Clean Cities (\$ per gal)		Regular Gasoline Information Reported by Clean Cities (\$ per gal)	
	Average Price	Number of Data Points	Average Price	Number of Data Points
New England	\$3.46	3	\$3.76	27
Central Atlantic	\$3.25	93	\$3.41	54
Lower Atlantic	\$3.11	47	\$3.34	62
Midwest	\$2.84	182	\$3.32	138
Gulf Coast	\$2.92	51	\$3.11	40
Rocky Mountain	\$3.11	65	\$3.42	94
West Coast	\$3.27	70	\$3.78	101
NATIONAL AVERAGE	\$3.04	511	\$3.45	516

The map to the right illustrates price differentials between E85 and regular gasoline by state, based on differentials between E85 and gasoline prices for each state (as opposed to the regional averages illustrated in Table 7). In this map, negative numbers represent prices for E85 lower than for gasoline, and positive numbers represent prices for E85 higher than gasoline, on a per-gallon basis. States not highlighted with a color did not have any E85 data points in the current report. As the map illustrates, the states with the most favorable E85 pricing were located in the Midwest region.



Tech Note: Ethanol (E85) contains about 30% less energy (BTUs) per volume than gasoline. Flexible fuel vehicles (FFVs) operating on E85 do not experience a loss in operational performance, but may experience a 25-30% decrease in miles driven per gallon compared to operation on gasoline. The appendix at the end of this report provides conversion factors for calculating E85 prices on a GGE and DGE basis. For a side-by-side comparison of available flexible fuel and other alternatively fueled vehicles, visit www.fueleconomy.gov.

PROPANE

Table 8 shows average prices for propane for vehicle use grouped by region, as well as regular gasoline prices, as provided by Clean Cities representatives. These prices were collected from across the country from Clean Cities coordinators, fuel providers, and other stakeholders on a voluntary basis. Some stations charge a different price for propane used in vehicles versus other uses. Where provided, the vehicle price has been included in this report.

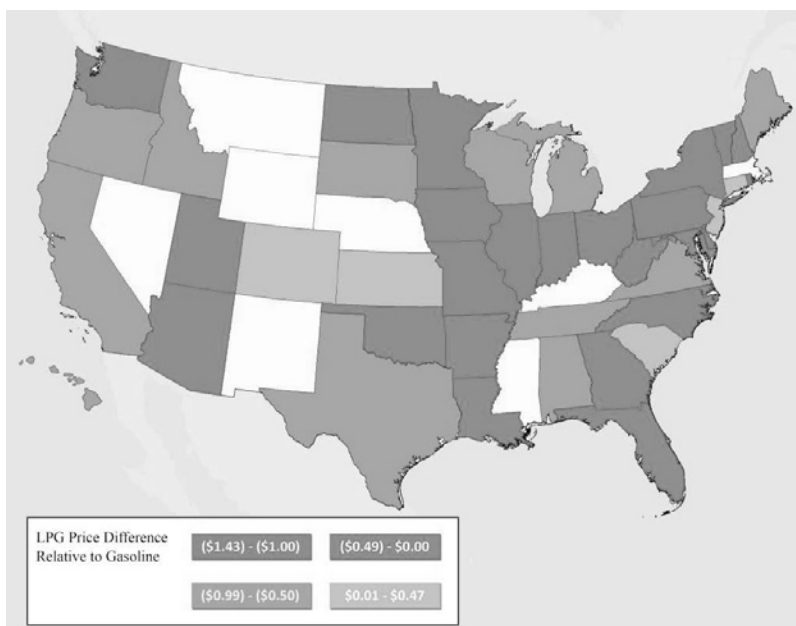
Table 8. Propane Average Prices by Region from Clean Cities Sources

	Propane Information Reported by Clean Cities (\$ per gal)		Regular Gasoline Information Reported by Clean Cities (\$ per gal)	
	Average Price	Number of Data Points	Average Price	Number of Data Points
New England	\$3.28	16	\$3.76	27
Central Atlantic	\$2.87	55	\$3.41	54
Lower Atlantic	\$3.00	46	\$3.34	62
Midwest	\$2.67	59	\$3.32	138
Gulf Coast	\$2.80	47	\$3.11	40
Rocky Mountain	\$3.22	58	\$3.42	94
West Coast	\$3.06	88	\$3.78	101
NATIONAL AVERAGE	\$2.96	369	\$3.45	516

As Table 8 illustrates, propane prices are lower than gasoline in all regions of the country on a per-gallon basis. Overall, propane was about 49 cents per gallon less than gasoline, with the largest average price differential of \$.72 per gallon found in the West Coast region. Propane prices in this report are from both private fleet refueling stations and public refueling sites that can provide propane for vehicles and for other uses.

The map to the right illustrates price differentials between propane and regular gasoline on a per-gallon basis, based on differentials between propane and gasoline prices for each state (as opposed to the regional averages illustrated in Table 8). In this map, negative numbers represent prices for propane lower than gasoline, and positive numbers represent propane prices higher than gasoline. States not highlighted with a color did not have any propane data points in the current report. As the map illustrates, the most favorable prices were found in the Midwest and Central Atlantic regions, as well as some states in the New England and West Coast regions.

Tech Note: Propane contains about 25% less energy (BTUs) per volume than gasoline and about 35% less energy (BTUs) per volume than diesel. The appendix at the end of this report provides conversion factors for calculating propane prices on a GGE and DGE basis.



BIODIESEL BLENDS: B20

Table 9 shows average prices for B20, a 20% biodiesel/80% diesel fuel blend, grouped by region, as well as regular diesel prices, as provided by Clean Cities representatives. These prices were collected from across the country from Clean Cities coordinators, fuel providers, and other stakeholders on a voluntary basis.

As Table 9 illustrates, prices for B20 are between 2 cents and 26 cents per gallon higher than conventional diesel fuel in six regions. This quarter's data shows one region, New England, with B20 prices less than diesel.

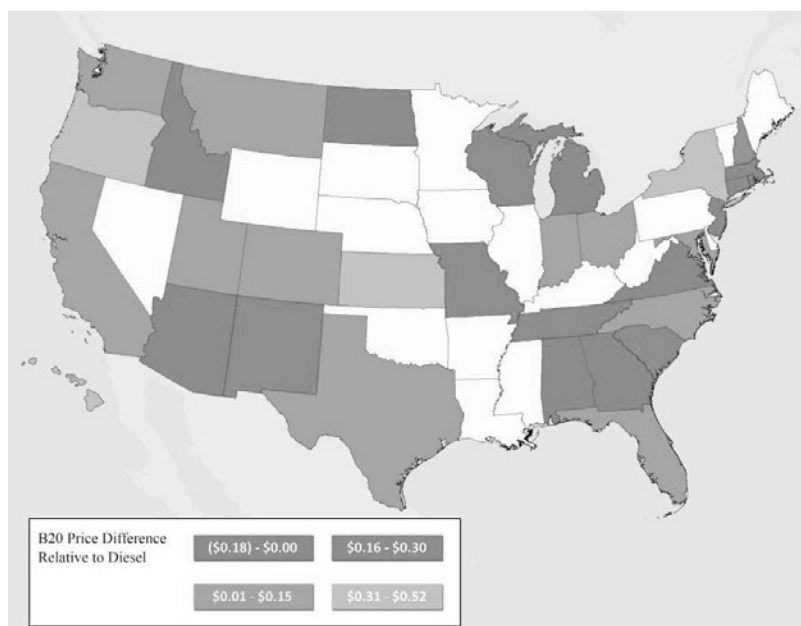
On average in the U.S., biodiesel in a B20 blend costs about 11 cents more per gallon than conventional diesel fuel, based on current information.

The map to the right illustrates price differentials between B20 and diesel on a per-gallon basis, based on differentials between B20 and diesel prices for each state (as opposed to the regional averages illustrated in Table 9). In this map, negative numbers represent prices for B20 lower than diesel, and positive numbers represent B20 prices higher than diesel. States not highlighted with a color did not have any B20 data points in the current report. B20 had favorable pricing (per gallon) in a number of states located around the country.

Tech Note: B20 contains only about 2% less energy (BTUs) per volume than diesel. The appendix at the end of this report provides conversion factors for calculating B20 prices on a GGE and DGE basis.

Table 9. Biodiesel (B20) Average Prices by Region from Clean Cities Sources

	Biodiesel (B20) Information Reported by Clean Cities (\$ per gal)		Diesel Information Reported by Clean Cities (\$ per gal)	
	Average Price	Number of Data Points	Average Price	Number of Data Points
New England	\$3.94	8	\$4.09	33
Central Atlantic	\$4.04	31	\$3.78	47
Lower Atlantic	\$3.85	22	\$3.83	42
Midwest	\$3.83	35	\$3.81	87
Gulf Coast	\$3.83	7	\$3.78	18
Rocky Mountain	\$3.95	17	\$3.89	45
West Coast	\$4.26	52	\$4.11	78
NATIONAL AVERAGE	\$4.02	172	\$3.91	350



BIODIESEL BLENDS: B99/B100

Table 10 shows average prices for high-level blends of biodiesel (99% or 100% biodiesel with diesel fuel), grouped by region, as well as regular diesel prices, as provided by Clean Cities representatives. These prices were collected from across the country from Clean Cities coordinators, fuel providers, and other stakeholders on a voluntary basis.

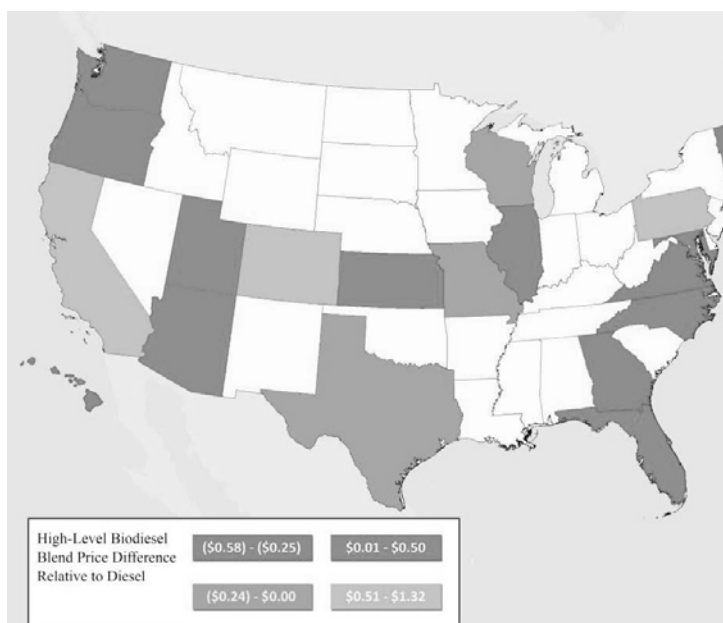
The price of B99/B100 is higher than the price of diesel fuel on a per gallon basis in four of the regions for which data was collected, ranging from 29 cents higher in the West Coast region to 70 cents higher in the Central Atlantic and Rocky Mountain regions. In the New England and Gulf Coast regions, prices for B99/B100 were lower than conventional diesel, by 39 cents and 21 cents, respectively. In the Midwest, the average prices for B99/B100 and conventional diesel were the same. On average across the nation, the price of B99/B100 is about 27 cents per gallon higher than the price of regular diesel.

The map to the right illustrates price differentials between high-level biodiesel blends and regular diesel on a per-gallon basis, based on differentials between biodiesel and diesel prices for each state (as opposed to the regional averages illustrated in Table 10). In this map, negative numbers represent prices for these blends that are lower than diesel, and positive numbers represent prices for these blends that are higher than diesel. States not highlighted with a color did not have any high-level biodiesel blend data points in the current report. Where data was available for this report, prices for B99/B100 (per gallon) were most favorable in states located in the New England and Lower Atlantic regions.

Tech Note: B100 contains about 10% less energy (BTUs) per volume than diesel. The appendix at the end of this report provides conversion factors for calculating B100 prices on a GGE and DGE basis.

Table 10. Biodiesel (B99/B100) Average Prices by Region from Clean Cities Sources

	Biodiesel (B99/B100) Information Reported by Clean Cities (\$ per gal)		Diesel Information Reported by Clean Cities (\$ per gal)	
	Average Price	Number of Data Points	Average Price	Number of Data Points
New England	\$3.70	4	\$4.09	33
Central Atlantic	\$4.48	5	\$3.78	47
Lower Atlantic	\$4.02	17	\$3.83	42
Midwest	\$3.81	5	\$3.81	87
Gulf Coast	\$3.57	3	\$3.78	18
Rocky Mountain	\$4.59	3	\$3.89	45
West Coast	\$4.40	25	\$4.11	78
NATIONAL AVERAGE	\$4.18	62	\$3.91	350



COMPARISON OF PRICES OF THIS REPORT VERSUS LAST REPORT

Table 11, below, summarizes the average prices collected for this report by region, and compares them to prices collected in the Price Report from July, 2013. It should be noted that a portion of the price changes could be attributed to differing sample sizes and locations between the two reports.

Table 11. Comparison of Prices, Last Price Report versus Current Price Report

		Price for October 2013 Period	Price for July 2013 Period	Price Differential October vs. July
Gasoline (\$ per gallon)	National Average	\$3.45	\$3.65	(\$0.20) / (6%)
	New England	\$3.76	\$3.88	(\$0.12) / (3%)
	Central Atlantic	\$3.41	\$3.63	(\$0.22) / (6%)
	Lower Atlantic	\$3.34	\$3.49	(\$0.15) / (4%)
	Midwest	\$3.32	\$3.63	(\$0.31) / (9%)
	Gulf Coast	\$3.11	\$3.42	(\$0.31) / (9%)
	Rocky Mountain	\$3.42	\$3.55	(\$0.13) / (4%)
	West Coast	\$3.78	\$3.93	(\$0.15) / (4%)
Diesel (\$ per gallon)	National Average	\$3.91	\$3.91	\$0 / 0%
	New England	\$4.09	\$4.07	\$0.02 / 1%
	Central Atlantic	\$3.78	\$3.81	(\$0.03) / (1%)
	Lower Atlantic	\$3.83	\$3.82	\$0.01 / 0%
	Midwest	\$3.81	\$3.86	(\$0.05) / (1%)
	Gulf Coast	\$3.78	\$3.82	(\$0.04) / (1%)
	Rocky Mountain	\$3.89	\$3.86	\$0.03 / 1%
	West Coast	\$4.11	\$4.08	\$0.03 / 1%
Compressed Natural Gas (\$ per GGE)	National Average	\$2.09	\$2.14	(\$0.05) / (3%)
	New England	\$2.53	\$2.57	(\$0.04) / (1%)
	Central Atlantic	\$2.19	\$2.22	(\$0.03) / (2%)
	Lower Atlantic	\$2.06	\$2.01	\$0.05 / 3%
	Midwest	\$1.87	\$1.86	\$0.01 / 0%
	Gulf Coast	\$2.02	\$2.03	(\$0.01) / (1%)
	Rocky Mountain	\$1.82	\$1.82	\$0 / 0%
	West Coast	\$2.31	\$2.43	(\$0.12) / (5%)
Ethanol (E85) (\$ per gallon)	National Average	\$3.04	\$3.23	(\$0.19) / (6%)
	New England	\$3.46	\$3.58	(\$0.12) / (3%)
	Central Atlantic	\$3.25	\$3.44	(\$0.19) / (5%)
	Lower Atlantic	\$3.11	\$3.25	(\$0.14) / (4%)
	Midwest	\$2.84	\$3.15	(\$0.31) / (10%)
	Gulf Coast	\$2.92	\$3.13	(\$0.21) / (7%)
	Rocky Mountain	\$3.11	\$3.08	\$0.03 / 1%
	West Coast	\$3.27	\$3.40	(\$0.13) / (4%)

Clean Cities Alternative Fuel Price Report

October 2013

Table 11. Comparison of Prices, Last Price Report versus Current Price Report

		Price October 2013 Period	Price for July 2013 Period	Price Differential October vs. July
Propane (\$ per gallon)	National Average	\$2.96	\$2.73	\$0.23 / 9%
	New England	\$3.28	\$3.14	\$0.14 / 4%
	Central Atlantic	\$2.87	\$2.76	\$0.11 / 4%
	Lower Atlantic	\$3.00	\$2.83	\$0.17 / 6%
	Midwest	\$2.67	\$2.47	\$0.20 / 8%
	Gulf Coast	\$2.80	\$2.30	\$0.50 / 22%
	Rocky Mountain	\$3.22	\$2.91	\$0.31 / 11%
	West Coast	\$3.06	\$2.99	\$0.07 / 2%
Biodiesel (B20) (\$ per gallon)	National Average	\$4.02	\$3.89	\$0.13 / 3%
	New England	\$3.94	\$3.92	\$0.02 / 0%
	Central Atlantic	\$4.04	\$3.87	\$0.17 / 5%
	Lower Atlantic	\$3.85	\$3.88	(\$0.03) / (1%)
	Midwest	\$3.83	\$3.54	\$0.29 / 8%
	Gulf Coast	\$3.83	\$3.86	(\$0.03) / (1%)
	Rocky Mountain	\$3.95	\$3.89	\$0.06 / 2%
	West Coast	\$4.26	\$4.13	\$0.13 / 3%
Biodiesel (B99/B100) (\$ per gallon)	National Average	\$4.18	\$4.19	(\$0.01) / 0%
	New England	\$3.70	\$3.80	(\$0.10) / (3%)
	Central Atlantic	\$4.48	\$4.62	(\$0.14) / (3%)
	Lower Atlantic	\$4.02	\$4.05	(\$0.03) / (1%)
	Midwest	\$3.81	\$3.96	(\$0.15) / (4%)
	Gulf Coast	\$3.57	\$3.70	(\$0.13) / (3%)
	Rocky Mountain	\$4.59	\$4.45	\$0.14 / 3%
	West Coast	\$4.40	\$4.37	\$0.03 / 1%

COMPARISON OF PRICES BY REGION FOR PUBLIC AND PRIVATE REFUELING STATIONS

Table 12, below, summarizes the comparison of fuel prices included in this report, separated into averages for privately-owned stations or stations available only to selected fleets (private refueling stations) and stations open to the public (public refueling stations). Private fleet fueling stations can typically negotiate prices lower than retail public stations, if they are willing to commit to purchasing large quantities of fuel over an extended period of time. However, private fleet pricing can sometimes be higher than retail public stations if there are unusual circumstances (remote locations, sites that use very small quantities of fuel, or special contracts where unique billing, accounting, or fleet service management fees are rolled into the price of the fuel).

As with the other prices in this report, all of these averages are prices with state and federal taxes included, using the protocols outlined at the beginning of this document.

Table 12. Comparison of Prices by Fuel Type, Region, and Station Type

		<i>Private Refueling Station Average Price</i>	<i>Public Refueling Station Average Price</i>
<i>Gasoline (\$/gallon)</i>	<i>National Average</i>	\$3.45	\$3.44
	New England	\$3.64	\$3.77
	Central Atlantic	\$3.43	\$3.41
	Lower Atlantic	\$3.21	\$3.36
	Midwest	\$3.42	\$3.31
	Gulf Coast	\$---	\$3.11
	Rocky Mountain	\$3.42	\$3.42
	West Coast	\$3.59	\$3.79
	<i>National Average</i>	\$3.74	\$3.93
<i>Diesel (\$/gallon)</i>	New England	\$3.95	\$4.12
	Central Atlantic	\$3.67	\$3.88
	Lower Atlantic	\$3.25	\$3.88
	Midwest	\$3.59	\$3.81
	Gulf Coast	\$4.03	\$3.76
	Rocky Mountain	\$3.84	\$3.89
	West Coast	\$3.93	\$4.13
	<i>National Average</i>	\$1.81	\$2.19
	New England	\$2.29	\$2.56
<i>Natural Gas (CNG) (\$/GGE)</i>	Central Atlantic	\$1.97	\$2.38
	Lower Atlantic	\$1.77	\$2.10
	Midwest	\$1.97	\$1.85
	Gulf Coast	\$1.67	\$2.03
	Rocky Mountain	\$1.57	\$2.01
	West Coast	\$1.65	\$2.36
	<i>National Average</i>	\$3.15	\$3.04
	New England	\$---	\$3.46
	Central Atlantic	\$3.35	\$3.24
<i>Ethanol (E85) (\$/gallon)</i>	Lower Atlantic	\$3.33	\$3.10
	Midwest	\$2.83	\$2.84
	Gulf Coast	\$---	\$2.92
	Rocky Mountain	\$3.32	\$3.11
	West Coast	\$3.45	\$3.26
	<i>National Average</i>	\$2.21	\$3.03
	New England	\$3.28	\$3.28
	Central Atlantic	\$2.09	\$3.11
	Lower Atlantic	\$---	\$3.00
<i>Propane (\$/gallon)</i>	Midwest	\$2.04	\$2.73
	Gulf Coast	\$2.03	\$2.89
	Rocky Mountain	\$1.87	\$3.24
	West Coast	\$2.56	\$3.10

Table 12. Comparison of Prices by Fuel Type, Region, and Station Type

		<i>Private Refueling Station Average Price</i>	<i>Public Refueling Station Average Price</i>
<i>Biodiesel (B20) (\$/gallon)</i>	<i>National Average</i>	\$4.08	\$3.99
	New England	\$3.97	\$3.89
	Central Atlantic	\$4.03	\$4.09
	Lower Atlantic	\$3.66	\$3.87
	Midwest	\$3.93	\$3.82
	Gulf Coast	\$3.79	\$3.83
	Rocky Mountain	\$3.62	\$4.00
	West Coast	\$4.41	\$4.20
<i>Biodiesel (B99/B100) (\$/gallon)</i>	<i>National Average</i>	\$4.64	\$4.16
	New England	\$--.--	\$3.70
	Central Atlantic	\$--.--	\$4.48
	Lower Atlantic	\$--.--	\$4.02
	Midwest	\$--.--	\$3.81
	Gulf Coast	\$4.43	\$3.14
	Rocky Mountain	\$--.--	\$4.59
	West Coast	\$4.74	\$4.37

HISTORICAL ALTERNATIVE FUEL PRICES FROM PREVIOUS REPORTS

The graphs on this page illustrate the historical prices for the alternative fuels included in these reports (specifically natural gas, propane, ethanol (E85), and biodiesel) relative to gasoline and diesel. These graphs include prices collected as part of the current Price Report activity, which began in September 2005. Natural gas (in GGE), propane, and ethanol (E85) have been graphed against gasoline prices, while natural gas (in DGE) and biodiesel have been graphed against diesel prices.

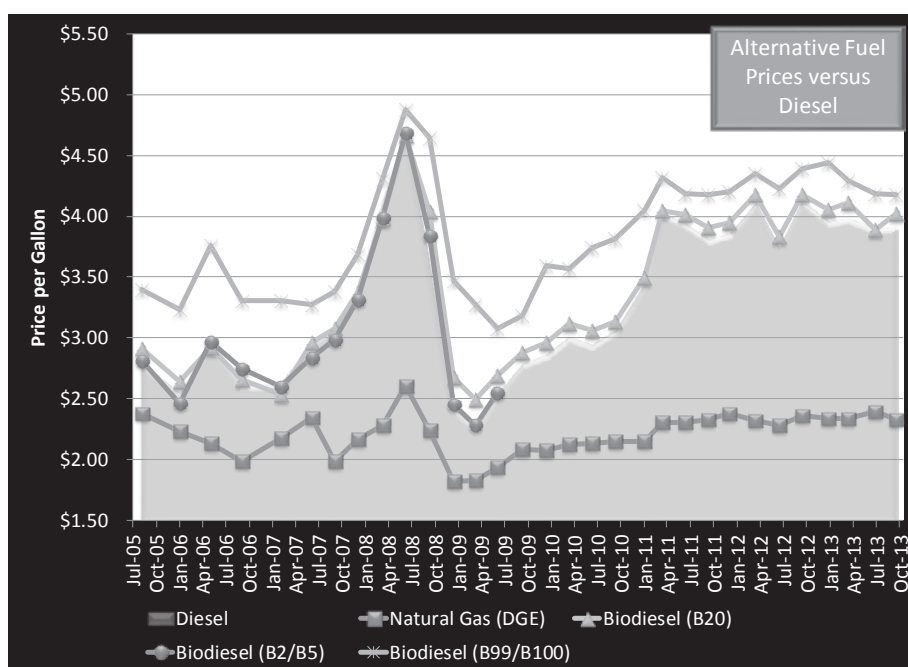
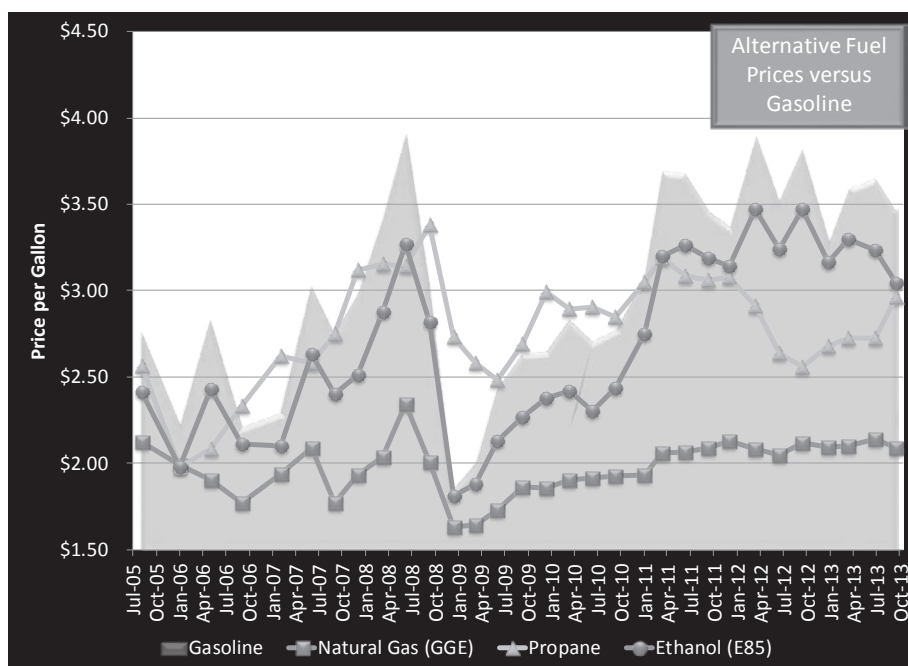


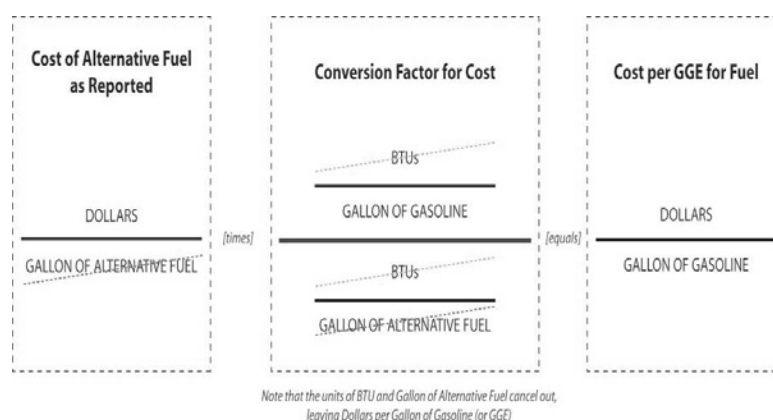
ILLUSTRATION OF CONVERSION FACTORS FOR FUELS

The standard lower heating values for fuels from the Transportation Energy Data Book 30 are listed below.

	Lower Heating Value
Gasoline	115,400 BTU/gal
Diesel	128,700 BTU/gal
Compressed Natural Gas	960 BTU/cubic foot
Ethanol	75,700 BTU/gal
Propane	83,500 BTU/gal
Biodiesel	117,093 BTU/gal

Conversion factors to establish prices in dollars per gasoline gallon equivalent (GGE) are illustrated below, and were developed using the lower heating values outlined above. The conversion factors are derived in the manner shown in the graphic to the right.

In the case of CNG, prices are provided to us in GGE, so no conversion is necessary (the representative heating value of CNG is provided above as a reference). To convert a price from dollars per gallon to dollars per GGE, multiply the price per gallon of the alternative fuel by the conversion factor.



	Conversion factor to GGE
CNG	1.00
Ethanol (E85)	1.41
Propane	1.38
Biodiesel (B20)	0.91
Biodiesel (B100)	0.99

Conversion factors to establish prices in dollars per diesel gallon equivalent (DGE) are illustrated below, and were developed using the lower heating values outlined above. To convert a price from dollars per gallon to dollars per DGE, multiply the price per gallon of the alternative fuel by the conversion factor.

	Conversion factor to DGE
CNG (in GGE)	1.12
Ethanol (E85)	1.58
Propane	1.54
Biodiesel (B20)	1.02
Biodiesel (B100)	1.10

ACKNOWLEDGEMENTS

The authors would like to acknowledge all of the contributors from the Clean Cities community who have provided prices for this report; we sincerely appreciate your continued dedication to the success of this report. The authors would also like to acknowledge the continued support of DOE for developing this report.

WOULD YOU LIKE TO PARTICIPATE?

If you would like to provide prices for alternative fuels in your region and be part of the data collection effort for this report, or if you have any questions, please contact:

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